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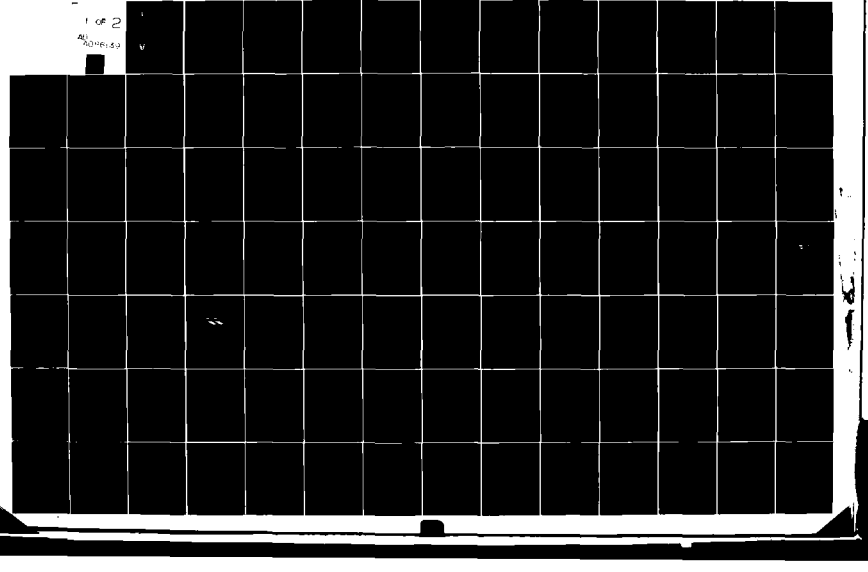

TECHNICAL REPORT RS-CR-80-1

HUMAN ENGINEERING DESIGN CRITERIA FOR MODERN CONTROL/DISPLAY COMPONENTS AND STANDARD PARTS

FINAL REPORT

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FOR

US Army Human Engineering Laboratory Detachment
Systems Engineering Directorate
US Army Missile Laboratory

MAY 1980

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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A study was conducted to identify requirements for modification of MIL-STD-1472B to include human engineering design criteria for modern controls and displays; and to reduce the incidence of requests for waiver of MIL-STD-1472 resulting from unavailability of standard parts. Recommended changes are presented with rationales and references.

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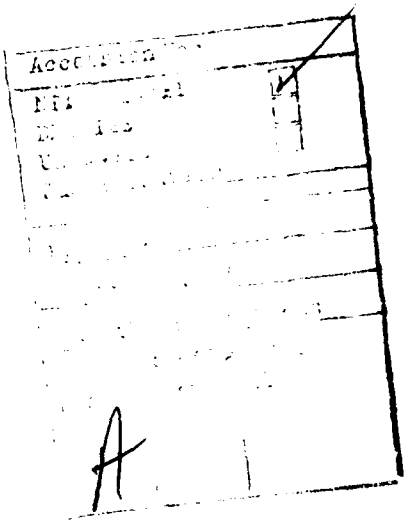
FOREWORD

This report describes the results of the technical effort performed by Essex Corporation under Contract No. DAAK40-79-C-0144.



1.0 INTRODUCTION

MIL-STD-1472 establishes general human engineering criteria for design and development of military systems, equipment, and facilities. The primary objective of human engineering criteria is to provide the designer with specifications and guidelines on design characteristics which have a direct and measurable impact on human performance. Ideally, such criteria are derived from empirical study and are regularly amended to reflect advances in both the human factors discipline and relevant engineering technologies. When properly developed and applied, human engineering design criteria can improve overall system performance in four major areas:

- Operability (reduced workload, error likelihood, and safety hazards)
- Maintainability (reduced downtime)
- Manning (optimized use of the workforce)
- Training (reduced training requirements and skill levels).

Paragraph 1.2 of MIL-STD-1472 states: "The purpose of this standard is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipment, and facility, and achieve effectiveness, simplicity, efficiency, reliability, and safety of system operation, training and maintenance." To effect these objectives, 1472 must achieve the following:

- The criteria must address the range and level of technologies currently being employed in military system development.
- The criteria must be relevant to actual system performance requirements.
- The standard must be responsive to practical constraints imposed by the system acquisition process.
- The content of the standard must be organized and formatted in a manner conducive to its effective application.

This report describes the results of a technical effort conducted by Essex Corporation to improve the adequacy of MIL-STD-1472, primarily in the areas of design criteria for modern control and display components, and to reduce the incidence of waiver requests. The specific objectives of the effort as mandated by the Technical Scope of Work were as follows:

- To incorporate criteria and guidelines for modern control, display, and other operator/maintainer interface hardware into MIL-STD-1472

and thereby enhance application of human engineering into development of military systems, equipment, and facilities

- To reduce or eliminate requests for waivers or exceptions to provisions of MIL-STD-1472 resulting from: 1) unavailability of standard parts or components meeting such provisions; and 2) conflict with other military specifications or standards where differences provide insignificant or marginal human engineering benefit.

The main body of the report is organized into four sections: Introduction, Technical Approach, Results, and Conclusions. In addition, two appendices have been included. Appendix A contains empirical data collected during the study on the various modern components. Appendix B contains tables describing points of conflict between MIL-STD-1472B and other specifications and standards.

2.0 TECHNICAL APPROACH

The technical approach developed to achieve the objectives of the present effort consisted of fourteen iterative tasks partitioned into two phases. The organization of these tasks is depicted in Figure 1.

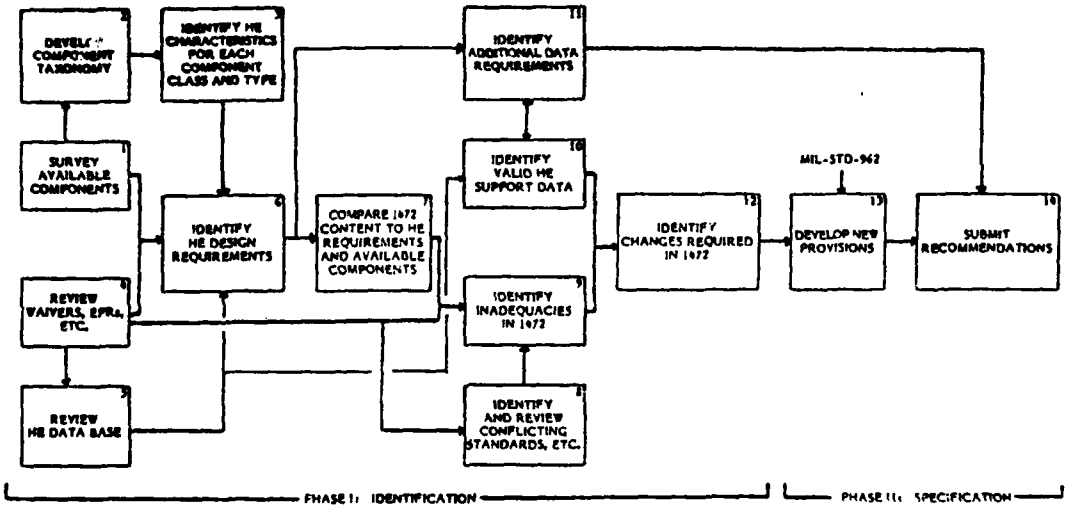


Figure 1: Program Tasks

The content and rationale of each of the tasks are described below.

2.1 Task 1 — Survey Available Components

Purpose — To identify component types currently employed in military systems which require interface with the human operator. This task served as the foundation of the program by ensuring that subsequent efforts focused on components currently used in military system design.

Method — A survey was conducted to identify generic components currently utilized in military design across the services. This task was composed of two concurrent worksteps:

1. Survey of government data sources:
   - Review of DoD Index of Specifications and Standards to identify component types

- Meetings with government procurement specialists
- Survey of human engineering specialists at various military installations.

2. Survey of industry data sources:

   - Review of the Electronic Engineering Master Catalog to identify manufacturers of components which have potential for military application
   - Survey of component manufacturers to acquire data on component specifications.

2.2 Task 2 — Develop Component Taxonomy

Purpose — To organize components identified in Task 1 according to category (i.e., standard or special, and modern or traditional); class (e.g., control); and type (e.g., pushbuttons).

Method — Components identified in Task 1 were organized using the following rationale:

- Categories:
  - standard — components which were military standard, for which a specification was available; or commercial items in general use, manufactured by two or more sources and listed in those companies' catalogs (paragraph 3.1.1 of Technical Scope of Work)
  - special — components not covered by standard definition
  - modern — components, devices, and techniques which are not covered by 1472
  - traditional — components, devices, and techniques which are covered by 1472.
- Classes: generic types of components, with distinguishable functions, initially derived from paragraph titles of 1472 (e.g., controls, displays, covers, fasteners, etc.). Additional classes were defined, as necessary, for modern components.
- Types: subcategories of classes reflecting distinctive design or use characteristics (e.g., toggle switches, rotary controls, tongue-and-slot catches, etc.). Additional types were defined, as necessary, for modern components.

This task focused on organizing identified components in a manner conducive to identifying inherent features relevant to human engineering design criteria.

2.3 Task 3 — Identify Human Engineering Characteristics for Each Component Class and Type

Purpose — To identify the physical and/or operational characteristics of each components class and type which can potentially affect human performance.

Method — Data contained in manufacturer's catalogs were reviewed to identify component characteristics relevant to human engineering. Human engineers specializing in Test and Evaluation of military equipment were surveyed to obtain inputs concerning component problem areas identified in HFE T&E. Baseline human engineering design considerations were derived from TOP 1-2-610 and HEDGE. These considerations were supplemented through a review of the HFE literature describing component characteristics that have been empirically demonstrated to have a significant effect on human performance.

2.4 Task 4 — Review Waivers, EPRs

Purpose — To determine the frequency of requests for waivers to MIL-STD-1472 resulting from: 1) non-availability of components meeting the standard; or 2) conflict with other specifications and standards. To identify action required to reduce the incidence of such waiver requests.

Method — Human engineers specializing in design and evaluation of military systems were surveyed to determine the frequency and nature of waiver requests. Where available, waivers and EPRs were acquired and reviewed to identify problem areas in the content or application of MIL-STD-1472.

2.5 Task 5 — Review Human Engineering Data Base

Purpose — To identify empirical data in the areas of human performance and human engineering and to determine the implications of such data for developing human engineering design criteria applicable to current military systems.

Method — Principal data sources in relevant areas (e.g., human engineering, biomechanics, ergonomics, anthropometry) were reviewed using the Essex computer-based information search and retrieval system. The following data bases were searched:

- NTIS
- ISMEC (Mechanical Engineering)
- COMPENDEX (General Engineering)

- Psychological Abstracts
- INSPEC (Electrical Engineering)

In addition, the Journal of Ergonomics and the Human Factors Journal indexes were reviewed. DDC and NASA STIF data bases were also searched. Human engineers specializing in industrial and military design were surveyed to acquire empirical data not contained in the open literature.

2.6 Task 6 — Identify Human Engineering Design Requirements

Purpose — To identify human engineering design requirements for components currently utilized in military system design.

Method — Components and characteristics identified in previous tasks were reviewed within the context of empirical data on human performance to determine what requirements existed for human engineering design criteria. The focus of this task was directed at isolating those component characteristics which have been empirically demonstrated to significantly affect human performance, primarily in the areas of speed and accuracy of response. These characteristics were then analyzed to determine what design requirements would optimize human performance.

2.7 Task 7 — Compare Content of 1472 to Human Engineering Design Requirements and Available Components

Purpose — To determine how well MIL-STD-1472 addressed the design requirements for available components identified in previous tasks.

Method — The content of MIL-STD-1472 was reviewed to: (1) determine the degree to which the standard provided guidance in the application and design of modern components, and (2) identify provisions which unnecessarily preclude the use of generally available parts.

2.8 Task 8 — Identify and Review Conflicting Standards and Specifications

Purpose — To identify areas of conflict between MIL-STD-1472 and other military standards and specifications which may result in requests for waiver of MIL-STD-1472.

Method — The original intent of this task was to review those standards and specifications which were frequently cited in requests for waiver of MIL-STD-1472 (Task 4). However, since comprehensive waiver history documentation was not available,

a review was conducted of 69 specifications and standards identified as having potential for conflicting with MIL-STD-1472. This review focused on analyzing the qualitative and quantitative provisions of the various specifications and standards to identify variance in design requirements which could result in unnecessary requests for waivers.

2.9 Task 9 — Identify Inadequacies in MIL-STD-1472

Purpose — To identify specific paragraphs in MIL-STD-1472 that fail to meet requirements for designing and/or evaluating the human engineering aspects of military systems currently in operation or under development.

Method — The content of MIL-STD-1472 was compared to data collected in previous tasks to identify areas of inadequacy. This effort focused on the following:

- Provisions in MIL-STD-1472 that fail to adequately address available components
- Provisions that are at variance with empirical data contained in the open literature
- Provisions that unnecessarily preclude the use of standard parts
- Provisions that conflict with requirements of other military specifications and standards.

2.10 Task 10 — Identify Valid Human Engineering Support Data

Purpose — To identify and analyze the human engineering and human performance data necessary to support changes and new provisions in MIL-STD-1472.

Method — Inadequacies in MIL-STD-1472 (Task 9) were compared to empirical data on human engineering and human performance (Task 5) to identify data which could be translated into qualitative or quantitative design criteria. In cases where MIL-STD-1472 conflicted with other military specifications and standards, the data were reviewed to determine the potential impact on human performance of modifying 1472 to conform to the requirements of the other documents.

2.11 Task 11 — Identify Additional Data Requirements

Purpose — To identify design characteristics which have been judged relevant to human performance in the military environment but for which no empirical data are available in the open literature.

Method — Valid human engineering data (Task 10) were compared to the design requirements identified in Task 6 to determine design considerations that could not be objectively resolved from available data. The areas for which existing data were inadequate were analyzed to determine requirements for further research.

2.12 Task 12 — Identify Changes Required in MIL-STD-1472

Purpose — To identify changes required in 1472 in order to: (1) incorporate criteria and guidelines for modern control, display, and other operator/maintainer interface hardware; and (2) to reduce or eliminate problems in meeting 1472 requirements with readily available hardware where such requirements may have marginal human engineering benefit.

Method — The outputs of Tasks 6, 8, 9, and 10 were analyzed to identify changes required to achieve the stated program objectives. The effort concentrated on the following factors:

- Type and degree of change necessary to meet HE design requirements identified in Task 6
- Data available to support change (output of Task 10)
- Rationale for change (projected problems if change is not implemented)
- Projected effect of change in terms of inclusion of modern components and reduction of waiver requests
- Relationship of change to other standards specifications, etc.

2.13 Task 13 — Develop New Provisions

Purpose — To organize and format required changes and support requirements.

Method — Required changes identified in Task 12 were organized and formatted in accordance with MIL-STD-962. The focus of this task was in developing provisions that are not only valid but also usable. To achieve this, emphasis was placed on making the content of a provision directly relatable to the requirements of military design and testing. Additionally, extensive consideration was given to the method of presenting associated support data in a manner conducive to their application. All recommended provisions were evaluated by the Technical Review Committee.

2.14 Task 14 — Submit Final Recommendations

Purpose — To finalize recommendations and to prepare and submit final report.

Method — Draft recommendations were submitted to cognizant technical personnel at the procuring activity for review and comment. Upon acceptance, recommendations were organized into a final report describing their content, rationale, and requirements for implementation. The final technical report was submitted in accordance with Section M, Contract Data Requirements List (DD Form 1423).

3.0 RESULTS

3.1 Phase I

The focus of Phase I was to identify changes required in MIL-STD-1472B to achieve the stated objectives. In terms of the first objectives, criteria for modern control and display components, the results of Phase I indicated a significant requirement for modification of the standard to incorporate design criteria necessary to optimize the human engineering characteristics of modern military systems. With regard to the second objective, reduction of waiver requests, the results of Phase I suggested that the incidence of requests for waiver of MIL-STD-1472 was not sufficient to warrant major modification of the standard. This conclusion, however, is somewhat tenuous due to the dearth of available information concerning request and issuance of waivers.

In organizing this report, the authors have included representative data tabularly in appendix. These appendices are not intended to be exhaustive of the data used in developing recommended changes to MIL-STD-1472B, but rather to provide the interested reader with examples of the data on which such changes were based.

3.2 Phase II

This section presents the results of Phase II of the present study in the form of recommended changes to MIL-STD-1472B. Section 3.2.1 contains recommended changes to paragraph 3.0 (Definitions) of MIL-STD-1472B; Section 3.2.2 contains recommended changes to paragraph 5.0 (Detailed Requirements) of MIL-STD-1472B. Recommended changes to 5.0 (Detailed Requirements) are presented in MIL-STD format, sequenced according to the affected paragraphs of MIL-STD-1472B. Each recommended change is accompanied by a brief description of the rationale for the change, and the references from which the data were extracted. In cases where supporting data are contained in Appendix A, the appendix page number is included.

3.2.1 Definitions

As a result of the expansion in scope of MIL-STD-1472, a number of definitions must be added to paragraph 3.0 of the standard. The following definitions are necessary to explicate recommended changes to the document:

Brightness Ratio — The difference in brightness between the visual task and surrounding field. For projection systems, the brightness ratio is equal to the light output of a projector (measured with no film in the projector) reflected off the screen (image brightness) divided by all the light falling on the screen (measured from the greatest viewing angle) other than that actually forming the image (nonimage brightness); i.e.,

$$BR = \frac{I}{I_n}$$

Contrast — The difference in brightness between two portions of a visual field. When the object (Bmin) is brighter than the background (Bmax), percent of contrast is defined as:

$$\%C = \frac{Bmax - Bmin}{Bmax} \times 100$$

When the background (Bmax) is brighter than the object (Bmin), the following equation is used:

$$\%C = \frac{Bmax - Bmin}{Bmin} \times 100$$

Contrast Ratio — The ratio of maximum luminance to minimum luminance such that:

$$CR = \frac{Bmax - Bmin}{Bmin}$$

For CRT displays, contrast ratio is equal to:

$$C_t = \frac{Bs + Bw}{Bs}$$

where B_s = the brightness of the screen from ambient light, and B_w = the brightness of the written line when ambient light is excluded.

Dot Matrix Display — A flat panel solid-state display which conveys alphanumeric, vector-graphic, or symbolic information through a combination of illuminated dots on a dark background, or V/V.

Electroluminescent Display — A self-illuminated display which emits cold light through the placement of a phosphor substrate in an alternating electrostatic field.

Exit Pupil — That area within a collimated beam in which the entire image formed by an objective lens is capable of being seen.

Field-of-View — The totality of all visual stimuli available to the fixated eye at any given time.

Flicker — A rapid alteration in visual perception induced by a corresponding rapid cyclic change in the intensity of the stimulus. Flicker is measured in terms of a threshold called the critical flicker-fusion frequency, a point at which a flickering stimulus fuses into a continuous one.

Luminance — The amount of light per unit area reflected from or emitted by a surface. It is measured in lumens per unit area per steradian and commonly expressed in foot-lamberts (fL) or millilamberts (mL). 1 fL = 1.08 mL.

Regeneration Rate — (Also referred to as refresh rate or frame rate.) The frequency measured in cycles per second with which a displayed image is updated. Flicker occurs when the regeneration rate of the display is below the critical fusion frequency which in turn depends on the ambient illumination, phosphor persistence, display brightness, bandwidth, volume of information per frame, system storage capacity, and system write/erase speed.

Resolution — The quality of a displayed image and a critical determinant of form recognition which manifests itself in CRT type displays as the number of raster lines per picture height.

Visual Angle — The angle subtended by an object of vision at the nodal point of the eye, usually given in minutes of arc. For angles less than 600 minutes:

$$\text{Visual angle (minutes)} = \frac{(57.3)(60)L}{D}$$

where L = the size of the object measured perpendicular to the line of sight, and D = the distance from the eye to the object.

3.2.2 Detailed Requirements

5.1 Control/Display Integration —

5.1.4 Control Display Ratio —

5.1.4.2 Range of Display Movement —

Recommended Change — Include the following statement: "When a wide range of display element movement is required followed by fine adjustment, a variable gain control should be considered."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Arnold (1977)

5.2 Visual Displays —

5.2.1.2.6 Display Failure Clarity

Recommended Change — Include the following statement: "For warning, caution, or advisory annunciators, the circuitry should be designed to fail-safe the annunciators to the on state should the lighting circuitry experience more than a transient failure."

Rationale — There is presently no recommendation in MIL-STD-1472B which prevents annunciators from being isolated from electrical power should the lighting control circuitry fail. Press-to-test checks (paragraph 5.2.2.1.14) will reveal the failure, but on an intermittent rather than continual basis.

Reference — LAMPS: Human Engineering Design Document (1978)

5.2.1.3.3 Orientation —

Recommended Change — Include the following qualification: "If self-reflection is a problem, perpendicular orientation shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Woodson and Conover (1966)

5.2.1.4 Coding —

5.2.1.4.2 Techniques —

Recommended Change — Rewrite paragraph as follows: "Displays shall be coded by color, size, location, shape, flash rate, alphanumerics, brightness, motion, or inclination, as applicable."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Technical review committee

5.2.1.4.4 Application —

Recommended Change — Add new provision: "If system objectives dictate that the searching, detection, or identification of critical information within a display must be responded to in less than ten seconds, then one or more of the coding techniques outlined in paragraph 5.2.1.4.2 shall be implemented."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-37)

5.2.1.4.5 Color Coding —

Recommended Change — Add new provision: "Color coding should be used when an observer must search for, pick out, or locate one or more characters from a matrix of displayed characters."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Williamson (1978)
Cahill and Carter (1976)
Christ (1975)
Saenz and Riche (1974)
Heglin (1973)
Beyer, et al. (1972)
Munns (1972)
Ketchell and Jenney (1968)
Burdick, et al. (1965)
Smith and Thomas (1964)
Smith (1963)

5.2.1.4.5.1 Choice of Color —

Recommended Change — Add new provision: "No more than five chromatic colors (seven including black and white) shall be used when coding information within a display. The choice of colors shall be in conformance with paragraph 5.4.1.4.5.1, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Cahill and Carter (1976) (A-33)
Burnette, cited in AGARD (1971) (A-33)
Meister and Sullivan (1969) (A-34)
Ketchell and Jenney (1968) (A-33)
Burdick (1965) (A-34)

5.2.1.4.5.2 Size and Spacing —

Recommended Change — Add new provision: "Alphanumeric and geometric or pictorial symbols shall subtend a minimum viewing angle of 20 arc minutes, although 26-30 arc minutes is preferred. To prevent color fusion there should be a spacing of at least three lines between symbols."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-34)
Semple, et al. (1973) (A-35)
Burnette, cited in AGARD (1971)
Burdick (1965) (A-35)

5.2.1.4.5.3 Ambient Illumination —

Recommended Change — Add new provision: "Ambient levels shall be above 0.001 ftC and chromatic illumination should be avoided.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-34)

5.2.1.4.5.4 Contrast —

Recommended Change — Add new provision: "Display contrast for a seven-color system shall be at least 10:1, and preferably between 20-30:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-34)

5.2.1.4.6 Shape Coding —

Recommended Change — Add new provision: "Shape coding should be used when a viewer must identify one or more objects from a matrix of displayed objects. Shape coding should also be used when the information represented on the display is qualitative in nature and when coding by color is not feasible. A maximum of 15 shapes shall be used, and only 6 under adverse display conditions. To augment object identification, color redundancy should be added. If possible, the symbols shall be associated with the objects they represent. Only simple, symmetrical symbols with enclosed areas and sharp angles or smooth curves should be used. Variations of a single geometric form shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Saenz and Riche (1974)
Heglin (1973) (A-36)
Van Cott and Kinkade (1972) (A-35)
Semple, et al. (1971) (A-35)
Ketchell and Jenney (1968) (A-36)
Smith and Thomas (1964)

5.2.1.4.7 Alphanumeric Coding —

Recommended Change — Add new provision: "Letters and numbers should be used for identification tasks and short code words which represent one of a kind type items. For three-character combinations, a number should be used for the first and third characters, and a letter for the middle character. There is no maximum number of alphanumeric combinations which can be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Christ (1975)
Heglin (1973) (A-37)
Van Cott and Kinkade (1972) (A-37)
Munns (1972)
Ketchell and Jenney (1968)
Smith and Thomas (1964)

5.2.1.4.8 Size Coding —

Recommended Change — Add new provision: "The maximum number of steps which should be used at any given time is three. To insure that the sizes are equally identifiable, the steps should increase on a logarithmic scale."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-37)
Ketchell and Jenney (1968) (A-37)

5.2.1.4.9 Brightness Coding —

Recommended Change — Add new provision: "Brightness coding is not generally recommended, but if used should employ no more than two levels (dim and bright). The higher level should represent items of primary interest with the lower level reserved for background or supplementary information."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Beyer, et al. (1973) (A-37)
Heglin (1973) (A-38)
Van Cott and Kinkade (1972) (A-38)
Ketchell and Jenney (1968) (A-38)

5.2.1.4.10 Motion Coding —

Recommended Change — Add new provision: "Motion coding is not generally advocated, especially for use on head-up displays. (However, if used, no more than two velocities are recommended.")

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Ketchell and Jenney (1968) (A-38)

5.2.1.4.11 Inclination Coding —

Recommended Change — Add new provision: "The angular orientation of lines on a display shall contain no more than 24 inclinations. Where rapid, accurate reading of the display is required, eight inclinations are recommended while four are preferred. The line length should be betweeen 0.2 and 0.3 inches. Intra-line orientation (measured in degrees) shall contain equally spaced deviations."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-38)
Van Cott and Kinkade (1972) (A-38)

5.2.1.4.12 Flash Coding —

Recommended Change — Include the following statement: "Flash coding shall be in conformance with paragraph 5.2.2.1.19, herein."

5.2.2.1.19 Flashing Lights —

Recommended Change — Rewrite paragraph as follows: "The use of flashing lights shall be minimized. Flashing lights may be used only when it is necessary to call the operator's attention to some condition requiring immediate action. The flash rate shall be in the range between one to five flashes per second, with the on and off phases of about equal duration. No more than three frequencies shall be used, with no more than two, and preferably one blinking signal on the display at any given time. The frequencies should be equally spaced on a logarithmic scale, with the faster flash rates representing the more critical information. The indicator shall be designed such that, if energized and the flasher device fails, the light will illuminate and burn steadily (see 5.3.2.4)."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Van Cott and Kinkade (1972) (A-38)
MIL-STD-1472B (1972)
Ketchell and Jenney (1968) (A-38)

5.2.2 Transilluminated Displays —

5.2.2.1.9 Luminance —

Recommended Change — Include the following statement: "The measured photometric brightness in the visible spectrum shall be 10 fL minimum at rated voltage."

Rationale — Expand to ensure conformance with paragraph 3.5.15 MIL-R-28803.

5.2.2.1.10 Luminance Control

Recommended Change — Include the following statement: "The design of the dimming feature shall be such that when the cap is turned to the full-dim position, a small diffused ring of light will be emitted through the lens."

Rationale — Expand to ensure conformance with paragraph 3.4.3 MIL-L-7961B and paragraph 1.2 of MIL-STD-1472B.

5.2.2.2.3 Lettering —

Recommended Change — Rewrite paragraph as follows: "Lettering should be all capitals, with font style similar to Futura Demibold type or Groton Extended engraving. Numerals should be similar to Futura Medium and Tempo Bold type or Groton Condensed engraving. Letter width-to-height ratio should be 1:1, and shall not be less than 3:5. The stroke width-to-height ratio should be 1:8 to 1:10, and for highly luminous letters, 1:12 to 1:20."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973)

5.2.3.1.4 Linear Scales —

Recommended Change — Include the following statement: "Non-linear scales should be used in situations where it is necessary to condense a large range into a small space in such a way as to permit sensitive readings at certain critical ranges of the scale."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)

5.2.3.1.5.1 Graduations —

Recommended Change — Include the following statement: "Graduation-interval values of 2 are less desirable than values of 1 or 5 and should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)

5.2.3.1.7.3 Mounting —

Recommended Change — Resolve disparity between MIL-STD-1472B and MIL-M-16034A, paragraph 3.5.2.2.1 which states that the clearance between the points index and graduated scale shall not exceed 0.10 inch nor be less than 0.03 inches.

5.2.3.3.1 Numerical Progression —

Recommended Change — Include the following statement: "If possible, displays utilizing moving scales and fixed pointers should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)
MIL-STD-1472B (Section 5.1.3.5)

5.2.4 Cathode Ray Tube (CRT) Displays —

This section should be expanded to include the following criteria.

5.2.4.1 Signal Size —

5.2.4.1.1 Alphanumerics —

Recommended Change — Add new provision: "Alphanumeric characters shall subtend not less than 12-15 minutes of visual angle. The characters shall be composed of upper case letters with a resolution of not less than ten lines per symbol height. Flight display alphanumerics shall subtend not less than 24 minutes of visual angle to insure adequate legibility under aircraft environmental conditions."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-9)
Van Cott and Kinkade (1972) (A-10)
Burnett, cited in AGARD (1971) (A-10)
Meister and Sullivan (1969) (A-10)
Ketchell and Jenney (1968) (A-10)
Gould (1968) (A-10)

5.2.4.1.2 Symbology —

Recommended Change — Add new provision: "Geometric and pictoral symbols shall subtend a minimum of 16 minutes of visual angle. For critical targets, or when a target of complex shape is to be distinguished from a non-target shape that is also complex, the target signal should subtend not less than 20 minutes of visual angle with a resolution of not less than 16-17 lines per symbol height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Semple, et al. (1971) (A-10)
Burnette, cited in AGARD (1971) (A-10)
Meister and Sullivan (1969) (A-10)

5.2.4.1.3 Height-to-Width Ratio —

Recommended Change — Add new provision: "The height-to-width ratio for alphanumerics shall be between 7:5 and 3:2. For alphanumerics in an airborne environment, the height-to-width ratio shall be between 2:1 and 1:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-11)
Rijnsdorp and Rouse (1977) (A-11)
Burnette, cited in AGARD (1971) (A-11)
McCormick (1970) (A-11)
Sherr (1970) (A-11)
Meister and Sullivan (1969) (A-11)

5.2.4.1.4 Stroke Width-to-Height Ratio —

Recommended Change — Add new provision: "Stroke width shall be in the range of 1:6 to 1:10 character height, with the thinner width used for light characters on a dark background. For alphanumerics in an airborne environment, the stroke width-to-height ratio should be 1:5."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Burnette, cited in AGARD (1971) (A-12)
Meister and Sullivan (1969) (A-12)
Gould (1968) (A-12)

5.2.4.1.5 Character Separation —

Recommended Change — Add new provision: "Wider spacing between characters shall be used for light symbols on a dark background rather than for dark symbols on a light background. Generally, character separation shall be between 25 and 63% of the symbol height, with the lower limit preferred under low ambient illumination (1.0 fL), or when the visual angle subtended by the characters is less than 16 minutes

of arc. When the illumination level is increased between 20 and 40 fL, character separation should be two times the symbol height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Semple, et al. (1971) (A-12)
Burnette, cited in AGARD (1971) (A-12)
Meister and Sullivan (1971) (A-12)

5.2.4.2 Viewing Conditions —

5.2.4.2.1 Viewing Distance —

Recommended Change — Add new provision: "A viewing distance of 18 inches shall be provided whenever practicable. When periods of scope observation will be short, or where dim signals must be detected, the viewing distance may be reduced to 14 inches. Due to eye strain and fatigue effects, viewing distances of less than 16 inches shall be avoided. The maximum viewing distance for a single seated operator shall be 28 inches, unless the screen size and symbol subtense are adjusted accordingly."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1977) (A-13)
Meister and Sullivan (1969) (A-13)

5.2.4.2.2 Viewing Angle —

Recommended Change — Add new provision: "The optimal horizontal angle for viewing a CRT display is 90° straight-on. No viewer should be seated at a viewing angle smaller than 45° and under no circumstances shall an observer be required to view the display from an angle smaller than 30°."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Van Cott and Kinkade (1972) (A-14)
Burnette, cited in AGARD (1971) (A-13)
Meister and Sullivan (1969) (A-14)

5.2.4.2.3 Display Size —

Recommended Change — Add new provision: "At a 28 inch viewing distance for a single seated operator, the screen size should be 12 inches in diagonal. This applies to both console based CRTs as well as CRTs used in flight control."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-13)
Semple, et al. (1971) (A-13)
Burnette, cited in AGARD (1971) (A-13)

5.2.4.3 Screen Luminance —

Recommended Change — Rewrite paragraph as follows: "The ambient illuminance shall not contribute more than 25% of screen brightness through diffuse reflection and phosphor excitation. A minimal screen luminance of 25mL shall be maintained, with a preferred screen luminance of 50mL. For CRTs used in dark adapted areas, screen luminance should be below 2.2mL. Under low ambient conditions (1.0 fL), light symbols on a dark background shall be used. Dark symbols on a light background shall be used under medium and high ambient illumination levels. A contrast of 88% is recommended while 94% is preferred.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977)
Heglin (1973)
Meister and Sullivan (1969)
Ketchell and Jenney (1968)
Gould (1968)

5.2.4.6 Ambient Illuminance —

Recommended Change — Include the following statement: "In general, the ambient illumination should be maintained at a level below the brightness of the CRT background. The operator should be visually adapted to the level of the scope brightness so as to maximize the visibility of near threshold targets. A pre-exposure duration of 2½ minutes shall be adhered to, if possible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — AFSC DH 1-3

5.2.4.7 Reflected Glare —

Recommended Change — Incorporate Section 5.2.4.8 into this section and rewrite paragraph as follows: "Reflected glare shall be minimized by proper placement of the scope relative to the light source. The light source should not be located within 60° of the viewer's central field-of-view. The light shall be diffused and distributed evenly over the work area, with the ratio between light and dark portions of the work surface not exceeding 7:1. In addition, glare shall be minimized by: proper placement of the scope relative to the light source, through the use of a hood or shield; by optical coatings or filters over the light source; or by directional or spectrum filters. All surfaces adjacent to the CRT shall have a dull matte finish. The reflectances of these surfaces shall be such that the resultant luminances will be consistent with the criteria established above."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Hultgren and Knave (1974)
Heglin (1973)

5.2.4.8 Phosphor —

Recommended Change — Add new provision: "The choice of phosphor depends primarily upon system application, but generally should be one which emits in the green region of the visible spectrum and reduces flicker. Short persistence phosphors (decay rates less than 10^{-3} sec.) should be used with displays having high regeneration rates and slow image movements. Medium persistence phosphors (decay rates not more than 0.1 sec.) should be used with moderate image movement, while the longer persistence phosphors are best for radar displays where information update is relatively infrequent, between 30 seconds and several minutes apart. Red symbols on a green background shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-2)
Semple, et al. (1971) (A-2)
Gould (1968) (A-2)
Burdick, et al. (1965) (A-2)

5.2.4.9 Shades of Gray —

Recommended Change — Change the paragraph on Electronically or Optically Generated Displays to 5.2.4.16 and retitle paragraph 5.2.4.9 to Shades of Gray. Add the following provision: "To insure target recognition and to provide realistic TV images, at least 10 shades of gray should be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Ketchell and Jenney (1968) (A-3)
Johnston (1968) (A-3)

5.2.4.10 Regeneration Rate —

Recommended Change — Add new provison: "The regeneration rate for a particular display depends on a number of variables, but generally shall be above the critical

frequency at fusion such that the occurrence of disturbing flicker is not perceptible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-3)
Semple, et al. (1971) (A-4)
Levine (1970) (A-6)
Meister and Sullivan (1969) (A-4)
Ketchell and Jenney (1968) (A-4)
Gould (1968) (A-5)
Barmack and Sinaiko (1966) (A-4)
Harshbarger (1965) (A-4)

5.2.4.11 Signal-To-Noise Ratio —

Recommended Change — Add new provision: "The signal-to-noise ratio shall be one which is large enough to achieve system objectives. Generally, a signal-to-noise ratio of 10:1 is considered satisfactory, 30:1 is considered good, and 50:1 is considered excellent."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Levine, et al. (1970) (A-6)
Meister and Sullivan (1969) (A-6)

5.2.4.12 Response Time —

Recommended Change — Add new provision: "The time from initiation of computer output until a new CRT page appears on the screen should be no longer than one second and shall not exceed three seconds."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-14)
Meister and Sullivan (1969)

5.2.4.13 Geometric Distortion —

Recommended Change — Add new provision: "The cumulative effects of all geometric distortion should not displace any point on the screen from its correct position by more than 2-5 percent of picture height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-15)

5.2.4.14 Graphics —

Recommended Changes — Add new provision: "Lines should be composed of at least 20 points per cm (50 points per inch) to provide the illusion of continuity."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-15)
Gould (1968) (A-15)

5.2.4.15 Cathode Ray Tube Displays (PPI) — This section on CRTs should be expanded to include PPI type displays.

5.2.4.15.1 Display Size

Recommended Change — Add new provision: "To insure optimal target detection, the display should be 7 inches in diameter for target sizes between 2 and 8mm. For target sizes between 12 and 16mm, the display should be between 12 and 16 inches in diameter."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Semple, et al. (1971) (A-17)
Meister and Sullivan (1969) (A-17)

5.2.4.15.2 Pip Size —

Recommended Change — Add new provision: "The pip shall subtend a visual angle of no less than 20 minutes of arc."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.3 Viewing Distance —

Recommended Change — Add the following provision: "The viewing distance for PPI type displays shall conform to paragraph 5.2.4.2.1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Van Cott and Kinkade (1972)
Meister and Sullivan (1969)

5.2.4.15.4 Pip Persistance —

Recommended Change — Add the following provision: "The pip shall appear for a minimum of .1 seconds."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.5 Scanning Rate —

Recommended Change — Add new provision: "The scanning rate for a 7-inch screen should be not less than 12 rpm, and preferably higher."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.6 Screen Luminance —

Recommended Change — Add new provision: "Screen luminance shall be between 10 and 100 fL, with the higher luminance recommended under brighter ambient conditions."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-18)

5.2.4.15.7 Ambient Illumination —

Recommended Change — Add new provision: "To insure pip detectability, ambient illumination should not be greater than 0.1 fC. If the operator must perform other visual tasks requiring higher brightness levels, the ambient illumination should not be brighter than 100 times the average brightness of the radar scope."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — AFSC DH 1-3
Heglin (1973)

5.2.6 Other Displays —

5.2.6.1 General —

5.2.6.1.1 Types —

Recommended Change — Rewrite paragraph as follows: "Where applicable, direct-reading counters, printers, plotters, flags, optical projection displays, electro-luminescent displays and dot matrix displays should be considered."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.2.6.6 Optical Projection Displays —

5.2.6.6.2 Seating Area —

Recommended Change — Include the following statement: "In order to insure comfort and good visibility, large meeting rooms with folding chairs should provide about 5 to 6 square feet of floor space per person. For smaller rooms with fixed seating, about 10 to 12 square feet of floor space per viewer should be allotted."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Kodak Publication No. S-3 (1978)

5.2.6.6.4.3 Contrast —

5.2.6.6.4.3.1 Brightness Ratio —

Recommended Change — Delete paragraph 5.2.6.6.4.3 and add new provision: "Under optimal ambient conditions, the brightness ratio for optically projected displays should be 500:1. The minimum brightness ratio for viewing charts, printed text, and other linework via slides or opaque projectors shall be 5:1. For projections which are limited in shadows and detail, such as animation and photographs with limited brightness range, the minimum brightness ratio shall be 25:1. For images which show a full range of colors (or grays in black-and-white photographs), the minimum brightness ratio shall be 100:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Kodak Publication No. S-3 (1978) (A-22)
Heglin (1973) (A-22)
IES Lighting Handbook (1972)

5.2.6.6.4.3.2 Direction of Contrast —

Recommended Change — Add new provision: "Contrast may be either light on a dark background or vice-versa, except where superposition is used. For subtractive superposition (at the source), data shall be presented as dark markings on a transparent background. For additive superposition (at the screen), data shall be presented as light markings on an opaque background. Colored markings against colored backgrounds of comparable brightness shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-STD-1472B (1974)
Heglin (1973) (A-23)
Van Cott and Kinkade (1972) (A-23)

5.2.6.6.5 Rear Projection —

Recommended Change — Add new provision: "Rear projection screens shall be used in those situations in which there are physical obstructions to front projection resulting in poor visibility, or in work areas requiring high ambient illumination for other activities. Under high ambient conditions, the projected image should be no more than 20 to 30 inches wide."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Kodak Publication No. S-3 (1978)
Van Cott and Kinkade (1972)

5.2.6.7 Light Emitting Diodes (LEDs) —

5.2.6.7.1 General —

Recommended Change — Rewrite paragraph as follows: "In general, the standard for LEDs will be the same as the requirements for Transilluminated Displays, paragraph 5.2.2 and Dot Matrix Displays, paragraph 5.2.6.8, unless specified below."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Technical Review Committee

5.2.6.8 Dot Matrix Displays —

5.2.6.8.1 General —

Recommended Change — "The design criteria listed below shall be applied to those flat panel (light emitting diodes, liquid crystal, CRT, and gas discharge) displays used exclusively for the presentation of alphanumeric and symbolic information."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

5.2.6.8.2 Application —

Recommended Change — Include the following paragraph "Dot matrix displays are excellent for applications involving interactive computer systems since they are capable of providing a capacious information interface between the man-computer system. Dot-matrix displays are also suitable for use in instruments, avionics, navigation and communication equipment where the presentation of alphanumeric, vector-graphic, symbolic or real-time information is required."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Technical Review Committee
Snyder and Maddox (1978)

5.2.6.8.3 Symbol Definition —

Recommended Change — Add new provision: "The smallest symbol definition for a dot mosaic shall be 5x7, with a 7x9 mosaic being preferred. If system requirements call for symbol rotation, a minimum definition of 8x11 is required, and 15x21 preferred. For stroke mosaics, 16 and 23 segment fonts should be used in preference to 17, 27 or 38 segment fonts."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Scanlan and Carel (1976) (A-29)
Vanderkolk, et al. (1975) (A-29)
Meister and Sullivan (1969)

5.2.6.8.4 Symbol Subtense —

Recommended Change — Add new provision: "Alphanumeric characters shall subtend not less than 12 minutes of visual angle, and preferably not less than 16 minutes. Flight display alphanumerics shall subtend not less than 24 minutes of visual angle."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Vanderkolk, et al. (1975) (A-29)

5.2.6.8.5 Viewing Angle —

Recommended Change — Add new provision: "The viewing angle for dot matrix displays shall conform to paragraph 5.2.4.2.2, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Vanderkolk, et al. (1975) (A-28)
Van Cott and Kinkade (1972)

Burnette, cited in AGARD (1971)
Meister and Sullivan (1969)

5.2.6.8.6 Emitter Characteristics —

5.2.6.8.6.1 Size —

Recommended Change — Add new provision: "The optimum emitter size depends upon the particular task. A 0.75mm dot should be used for reading tasks and a 1.5mm dot should be used for search tasks. If the display is to be used for both types of tasks, the dot should be between 1.0 and 1.2mm."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Scanlan and Carel (1976)

5.2.6.8.6.2 Spacing —

Recommended Change — Add new provision: "A dot spacing/size ratio of 0.5 should be adhered to, if possible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Snyder and Maddox (1978) (A-29)

5.2.6.8.6.3 Shape —

Recommended Change — Add new provision: "Either circular or square emitters shall be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Vartabedian (A-29)

5.2.6.8.6.4 Color —

Recommended Change — Add new provision: "Monochromatic matrix displays shall use the following emitter colors: In order of preference; green (555mu), yellow (575mu), orange (585mu), and red (660mu). Blue emitters should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Vanderkolk, et al. (1975) (A-28)

5.2.6.8.7 Luminance —

Recommended Change — Add new provision: "The minimum screen luminance shall be 21mL. A contrast ratio of at least 8.5:1 should be provided, if possible."

Rationale —Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Snyder and Taylor (1979) (A-28)
Snyder and Maddox (1978) (A-28)

5.2.6.8.8 Regeneration Rate —

Recommended Change — Add new provision: "The regeneration rate shall conform to paragraph 5.2.4.10, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Riley (1977) (A-29)
Scanlan and Carel (1976) (A-29)

5.2.6.9 Electroluminescent Displays —

5.2.6.9.1 General —

Recommended Change — Include a section entitled Electroluminescent Displays and add the following provision: "Electroluminescent display resolution shall be equivalent to that recommended for CRT type displays as outlined in paragraphs 5.2.4.1.1 and 5.2.4.1.2. Symbol definition will be the same as that recommended for stroke mosaic font, paragraph 5.2.6.8.3. If the display will be used in an airborne environment, the information displayed shall be of sufficient contrast and brightness to be seen in up to 10,000 foot candle ambient conditions. Additional design, safety and human engineering requirements shall be accomplished in conformance with MIL-STD-884, MIL-STD-454, MIL-H-46855, and 5.2.2 herein."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Van Cott and Kinkade (1972)
King, et al. (1970)
Ciuffini (1966)
MIL-STD-884
MIL-STD-454
MIL-H-46855

5.2.6.9.2 Application —

Recommended Change — Include the following paragraph: "Electroluminescent displays can be used wherever system requirements dictate the use of transilluminated displays. In addition, they can replace existing mechanical instrumentation while offering the following advantages: conservation of instrument panel space, lighter weight, lower power requirements, lack of heat production, uniform distribution of illumination, longer life, elimination of parallax and display flexibility. Electroluminescent displays should also be used for those applications in which a sudden failure of a lamp could result in catastrophic consequences (See 5.2.2.1.13)."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Reynolds (1971)
King, et al. (1970)
Frost and Hoffman (1968)
Peterson and Smith (1966)
Stenson (1966)

5.4 Controls —

5.4.1 General Criteria —

5.4.1.1 Selection —

Recommended Change — Add new paragraph, 5.4.1.1.5, Continuous-Adjustment Controls - Continuous-adjustment controls shall be used when precise adjustments along a continuum are required, or when a large number of discrete settings (more than 24) is needed.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Van Cott and Kinkade (1972)

5.4.1.1.4 Detent Controls —

Recommended Change — Retitle paragraph to read "Discrete-Adjustment (Detent) Controls —"

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — Arnold (1977)

5.4.1.1.4 Detent Controls —

Recommended Change — Include the following statement: "Detent controls shall not be used for automated functions, for increasing-decreasing functions, or for those circumstances requiring momentary positioning."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — MIL-STD-454F

5.4.1.2 Direction of Movement —

5.4.1.2.3 Operator-Control Orientation —

Recommended Change — Expand paragraph to include: "Vehicle operator stations shall be designed to permit the operator to face in the direction of primary vehicle movement when operating controls effecting vehicle movement."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Arnold (1977)

5.4.1.3 Arrangement and Grouping —

5.4.1.3.1 Grouping —

Recommended Change — Expand the paragraph to include the following: "When multi-function controls are used, related functions shall be grouped together within and between modes."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee.

5.4.1.4 Coding —

5.4.1.4.3 Size-Coding —

Recommended Change — Expand the paragraph to include the following: "When knob diameter is used as the coding parameter, differences between diameters shall not be less than 13mm (0.5 in.). When knob thickness is the coding parameter, differences between thicknesses shall not be less than 10mm (0.4 in.).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Bradley, cited in Arnold (1977)

5.4.1.4.4 Shape Coding —

Recommended Change — Expand the paragraph to include the following: "If possible, the shapes chosen shall be associated with or resemble control function."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Van Cott and Kinkade, cited in Arnold (1977)

5.4.1.8 Prevention of Accidental Activation —

5.4.1.8.4 Methods —

Recommended Change — Add new provision, h, "When software is involved, provide guarding by requiring concurrent or consecutive switch activations."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.4.2 Rotary Controls —

5.4.2.1.1.5 Contrast —

Recommended Change — Rewrite paragraph as follows: "A reference line shall be provided on rotary switch controls. The contrast of the reference line to the skirt shall not be less than 2.5 for gray panels and 9 for black panels, when determined as specified in MIL-P-7788."

Rationale — Avoid conflict with MIL-K-25049 and MIL-P-7788.

Reference — MIL-P-7788 and MIL-K-25049

Note — MIL-P-7788 presents the following formula for contrast (C):

$$C = \frac{B_2 - B_1}{B_1}$$

where B_1 is background brightness and B_2 is the brightness of the marking.

5.4.2.1.1.7 Dimensions, Resistance, Displacement, and Separation — (Figure 3).

Recommended Change — Under "Displacement" a minimum of 15^{o} should be specified for controls where visual positioning is possible; 30^{o} minimum displacement should be required for tactually positioned controls.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3 (1977)

5.4.2.1.1.7 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Under "Dimensions" the minimum width should be .25 inch.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3 (1977)

5.4.2.1.3 Thumbwheel Controls —

5.4.2.1.3.8.2 Continuous Thumbwheel Controls —

Recommended Change — Add the following statement: A detent shall be provided for thumbwheel controls having an off position.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Farrell and Booth (1975)

5.4.2.1.3.9 Separation — (Figure 5).

Recommended Change — Change minimum separation requirement to 6.5mm (.25 in.). Add preferred separation of 9.5mm (.375 in.).

Rationale — Avoid conflict with MIL-STD-803, and reflect empirical data on human performance.

LOAD	SPECIFICATION	HANDLE				TURNING RADIUS			
		LENGTH		DIAMETER		RATE BELOW 100 RPM		RATE ABOVE 100 RPM	
		mm	in.	mm	in.	mm	in.	mm	in.
LIGHT LOADS: Less than 2.27kg (5 lb) (Wrist and finger movement)	MINIMUM	25.4	1	9.525	3/8	38.1	1½	12.7	1/2
	PREFERRED	38.1	1½	12.7	1/2	76.2	3	57.15	2½
	MAXIMUM	76.2	3	15.875	5/8	127.0	5	114.3	4½
HEAVY LOADS: More than 2.27kg (5 lb) (Arm movement)	MINIMUM	76.2	3	25.4	1	190.5	7½	127.0	5
	PREFERRED	95.25	3¾	25.4	1	--	--	--	--
	MAXIMUM	--	--	38.1	1½	508.0	20	228.6	9

Figure 7a. Continuous Adjustment Cranks

Reference — AFSC-DH 1-3 (1977)
Van Cott and Kinkade (1972)

5.4.2.1.3.9 Separation —

Recommended Change — Change minimum diameter to 25.4mm (1.0 in.) and maximum diameter to 76.2mm (3.0 in.).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — MIL-C-81774

5.4.2.2.2 Cranks —

5.4.2.2.2.3 Dimensions, Resistance, and Separation —

Recommended Change — Crank dimensions, resistance, and separation shall conform to the criteria in Figure 7a.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3
Arnold (1977)

5.4.3 Linear Controls —

5.4.3.1 Discrete Linear Controls —

5.4.3.1.1 Pushbuttons (Finger- or Hand-Operated) —

5.4.3.1.1.4 Channel or Cover Guard —

Recommended Change — Include the following statement: "When the guard is in the open position, its location shall not interfere with the operation of the protected device or adjacent controls."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-C-81774A, paragraph 3.4.2
LAMPS: Human Engineering Design Document (1978)

5.4.3.1.1.5 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Add the following statement: "When rectangular pushbuttons are used, dimensions, resistance, displacement, and separation between adjacent edges of pushbuttons shall conform to the criteria in Figure 12."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.4.3.1.1.5 Dimensions, Resistance, Displacement and Separation —

Recommended Change — Resolve disparity for pushbutton resistance forces. MIL-STD-1132A allows resistances of up to 112 ounces, while MIL-S-227/10/17F recommends a 30-ounce minimum and a 60-ounce maximum. Both documents are discrepant with the resistance in MIL-STD-1472B which requires a minimum of 10 ounces and a maximum of 40 ounces. There are no data in the human engineering literature that would substantiate modifying this provision to concur with the other documents. It is, therefore, recommended that MIL-S-227/10/17F and MIL-STD-1132A be reviewed to determine the origin of their respective requirements, and, if appropriate, these documents should be brought into accord with MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.3 Keyboards —

5.4.3.1.3.2 Layout and Configuration —

a. Numeric Keyboard

Recommended Change — Rewrite the paragraph as follows: The configuration of the keyboard which shall be used to enter solely numeric information shall be a 3x3+1 matrix, with the digits 1, 2 and 3 reading left-to-right in the top row and the zero digit centered on the bottom row (i.e., telephone style).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Conrad and Hull (1968, reported in Alden, et al. (1972)) (A-40)

5.4.3.1.3.3 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity for keyboard resistance forces MIL-S-8805/79A calls for a resistance of 6 ± 2 ounces, which exceeds the 5.3 ounce maximum criterion set forth in MIL-STD-1472B. There are no data contained in the human engineering literature to support modifying MIL-STD-1472 to conform to MIL-S-8805. Therefore, it is recommended that the origin of the MIL-S-8805 provision be identified and, if appropriate, that requirement changed to concur with MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.3.5 Multiple Keyboards —

Recommended Change — (new paragraph) Systems containing more than one keyboard shall maintain the same configuration for alphanumeric, numeric and special function keys throughout the system.

Rationale — Problem area reported in HFE T&E during DT II.

Reference — Waters (1979)

5.4.3.1.4 Toggle Switch Controls —

5.4.3.1.4.2 Accidental Activation —

Recommended Change — Add the following statement: "Resistance of lift-to-unlock mechanisms shall not exceed 48 oz."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — MIL-C-81774A.

5.4.3.1.4.2 Accidental Activation —

Recommended Change — Include the following statement: "If a cover guard is used, its location when open shall not interfere with the operation of the protected device or adjacent controls."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-C-81774A, paragraph 3.4.2
Lamps: Human Engineering Design Document (1978)

5.4.3.1.4.3 Dimensions, Resistance, Displacement, and Separation — (Figure 11)

Recommended Change — Adjust table entries as follows: minimum arm length for use by gloved finger = 18mm (.7"); minimum separation for use by gloved finger = 51mm (2.0"); minimum displacement for 2-position toggle switch = 25^{o}.

Rationale — Change is recommended to reduce or eliminate requests for waivers or exceptions to MIL-STD-1472 resulting from unavailability of standard parts meeting the provision.

Reference — Component survey under the present effort

Note: Minimum arm length for use with gloved hand recommended by Woodson and Conover is 19mm (.75").

5.4.3.1.4.3 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity toggle switch displacement, MIL-S-9419D requires a minimum lever travel of 3 to 7 degrees, for a 3-position toggle switch, while MIl-S-81619/1A calls for a displacement of 17 degrees. Both documents are discrepant with MIL-STD-1472B which requires a toggle displacement of 18 degrees. There are no data in the human engineering literature to support modifying MIL-STD-1472 to conform to the cited documents. It is recommended that the subject documents be reviewed to determine the rationale for their respective provisions, and, if appropriate, those provisions be modified to conform to MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.5 Legend Switches —

5.4.3.1.5.1 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity for legend switch resistance. MIL-S-22885/90 requires an activation force between 16 and 80 ounces, while MIL-STD-1472B requries a 10-ounce minimum and a 40-ounce maximum.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.6 Pushbutton-Wheel Switches — Recommended Change: (new paragraph)

5.4.3.1.6.1 Application — Pushbutton-wheel switches should be used for discrete functions when a number of detented positions are required in a fixed sequence (e.g., channel testing).

5.4.3.1.6.2 Shape — The pushbutton surface shall conform to the requirements of paragraph 5.4.3.1.1.2.

5.4.3.1.6.3 Positive Indication — The design of the switch shall provide the operator with a positive indication that the rotary wheel has advanced.

5.4.3.1.6.4 Positions — The number of positions on the rotary wheel should be limited to that required for system operation, i.e., there should be no "dead" positions.

5.4.3.1.6.5 Visibility — The display window shall not obscure any portion of the displayed numeral when viewed from the normal operating position. The display window shall be placed adjacent to the pushbutton such that the operator's hand does not obscure the window during operation.

5.4.3.1.6.6 Design of Rotary Wheel Characters — Rotary wheel characters shall be displayed to conform to paragraph 5.5.5.

5.4.3.1.6.7 Numeral Separation — Numerals on the rotary wheel shall have sufficient separation to ensure that only the displayed numeral is visible.

5.4.3.1.6.8 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement and separation between adjacent edges of pushbutton-wheel switches shall conform to paragraph 5.4.3.1.1.5.

5.4.3.1.6.9 Rotary Wheel Resistance — The rotary wheel advance mechanism's resistance shall be elastic, building up, then decreasing as each position is approached, so that the wheel snaps into position without stopping between adjacent positions.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-52)

5.4.3.1.7 Rocker Switches — Recommended Change (new paragraph)

5.4.3.1.7.1 Application — Rocker switches should be used for functions which require two discrete positions. Rocker switches with three or more positions shall be used only where the use of a rotary control, legend switch control, etc., is not feasible or when the rocker switch is a spring-loaded, center-position-off type.

5.4.3.1.7.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical dangerous or hazardous conditions would result), channel guards or other equivalent means shall be provided.

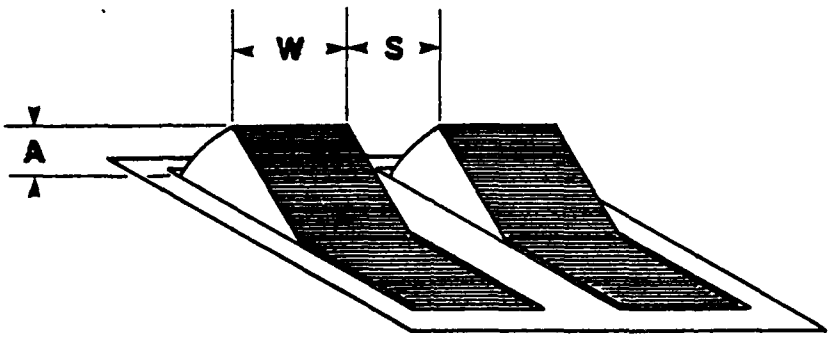
5.4.3.1.7.3 Positive Indication — A positive indication of control activation shall be provided (e.g., snap feel, audible click, associated or integral light, etc.).

5.4.3.1.7.4 Dimensions, Resistance, Displacement, and Separation — Dimension, resistance, displacement and separation between adjacent edges of rocker switches shall conform to the criteria in Figure 12a.

5.4.3.1.7.5 Resistance — Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

5.4.3.1.7.6 Orientation — Rocker switches shall be vertically oriented with activation of the upper "wing" turning the equipment or component on, causing the quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation and actuation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.



	W WIDTH	RESISTANCE
MINIMUM	19mm (0.75")	10 oz
MAXIMUM	38mm (1.5")	40 oz

	S SEPARATION	A DISPLACEMENT	
		2 POSITION	3 POSITION
MINIMUM	13mm (0.5")	30°	15°
MAXIMUM	— — —	120°	60°
OPTIMUM	50mm (2.0")	— — —	25°

FIGURE 12A. ROCKER SWITCHES

Reference — Technical review committee (A-51)

5.4.3.1.8 Multifunction Switches — Recommended Change: (new paragraph)

5.4.3.1.8.1 Application — Multifunction switches should be used when design considerations dictate the use of non-dedicated controls (e.g., single-operator workstations having multiple modes of operation but limited panel space).

5.4.3.1.8.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards, software guarding, or other equivalent means shall be provided.

5.4.3.1.8.3 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement, and separation between adjacent edges of multifunction switches shall conform to the criteria in paragraph 5.4.3.1.1.5.

5.4.3.1.8.4 Positive Indication — A positive indication of control activation shall be provided (e.g., snapfeel, audible click, or integral light). In addition, the displayed function label should be highlighted upon selection. (See paragraph 5.16.1.3)

5.4.3.1.8.5 Location — Functions which occur in more than one mode shall be assigned to the same switch in each mode, unless otherwise dictated by sequential or functional grouping. Related functions shall be grouped together within and between modes.

5.4.3.1.8.6 Labelling — Labels for multifunction switches shall be displayed adjacent to the related control such that the control-label relationship is unambiguous.

5.4.3.1.8.7 Location of Primary Controls — The most important and frequently used controls for each mode shall have the most favorable position with respect to ease of reaching.

5.4.3.1.8.8 Other Requirements —

a. The mode-select switch shall be a dedicated control.

b. The mode selected shall be prominently displayed adjacent to the mode-select switch.

c. A list of available modes of operation shall be provided. The list shall be located and organized in such a manner as to permit the operator to readily determine what action is required to obtain any particular mode.

d. Function label characteristics shall conform to the criteria applicable to the display medium used (e.g., dot matrix).

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-41)

5.4.3.1.9 PC Switch Controls —

5.4.3.1.9.1 Application — PC switches should be used when manual programming functions are required in systems employing printed circuit boards.

5.4.3.1.9.2 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement and separation between adjacent PC switch actuators shall conform to the following:

a. Dimensions of actuators shall be sufficient to permit error-free manipulation by the operator using some commonly available stylus (e.g., pencil or pen). The design of the actuators shall not require the use of a special tool for manipulation.

b. Actuator resistance shall be limited to that required to avoid inadvertant activation under expected use conditions. Resistance should gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

c. When actuators are slide-type, they shall have sufficient travel (displacement) to permit easy recognition of switch setting. At a minimum, the travel should be two times the length of the actuator. When actuators are rocker-type, they shall be designed such that the actuated wing is flush with the surface of the module.

d. Actuators shall have sufficient separation to permit error-free manipulation by the operator (i.e., the stylus cannot inadvertantly contact adjacent actuators).

5.4.3.1.9.3 Shape — The surface of the actuator shall be indented to accept the point of the stylus. The indentation shall be of sufficient depth to avoid slippage of the stylus during manipulation.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-50)

5.4.3.1.10 Miniature Controls — Recommended Change: (new paragraph)

5.4.3.1.10.1 Application — Miniature controls may be used when severe space limitations exist. Miniature controls shall not be used when available space is adequate for standard-sized controls.

5.4.3.1.10.2 Dimensions, Resistance, Displacement, and Separation — When design constraints dictate the use of miniature controls, the dimensions and separation of the controls shall be the maximum permitted by the available space. Whenever practicable, resistance and displacement of miniature controls shall conform to the criteria specified for the standard size of that type of control.

5.4.3.1.10.3 Other Requirements — All other design considerations (e.g., labelling, orientation, etc.) shall conform to the requirements specified for the standard size of that type of control.

5.4.3.1.11 Slide Switch Controls — Recommended Change: (new paragraph)

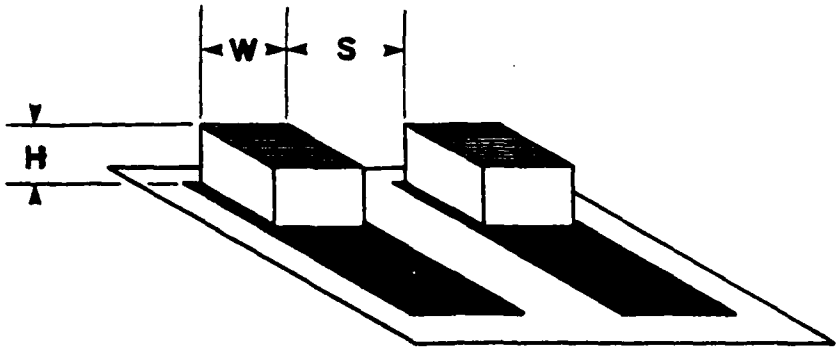
5.4.3.1.11.1 Application — Slide switch controls may be used for functions which require two dicrete positions. Slide switch controls should be used for functions which require a number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (e.g., audio settings across frequencies).

5.4.3.1.11.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards or other equivalent means will be provided.

5.4.3.1.11.3 Dimensions, Resistance, and Separation — Dimensions, resistance and separation of slide switch handles shall conform to criteria in Figure 12B.

5.4.3.1.11.4 Detents — Detents shall be provided for each control setting. Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of stopping between positions.

5.4.3.1.11.5 Orientation — Whenever practicable, slide switches shall be vertically oriented with movement of the slide up or away from the operator turning the equipment or component on, causing the quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation or actuation slide switches shall be employed only for compatibility with the controlled function or equipment location.



	DIMENSIONS			RESISTANCE
	H ACTUATOR HEIGHT		W ACTUATOR WIDTH	
MINIMUM	6.3mm (0.25")	13mm (0.5")	3mm (0.125")	10 oz
MAXIMUM	50mm (2.0")	50mm (2.0")	25mm (1.0")	40 oz

	SEPARATION S		
	SINGLE FINGER OPERATION	SINGLE FINGER SEQUENTIAL OPERATION	SIMULTANEOUS OPERATION BY DIFFERENT FINGERS
MINIMUM	19mm (0.75")	13mm (0.5")	16mm (0.625")
OPTIMUM	50mm (2.0")	25mm (1.0")	19mm (0.75")

FIGURE 12B. SLIDE SWITCHES

5.4.3.1.11.6 Positive Indication — Slide switch controls shall be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle. The pointer shall extend to, but not obscure, the shortest scale graduation marks. When two or more slide switches are grouped together, each switch shall be provided with its own scale graduation marks and setting indications.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Technical review committee (A-54)

5.4.3.2 Continuous Adjustment Linear Controls — Recommended Change: (new paragraph)

5.4.3.2.3 Joystick Controls —

5.4.3.2.3.1 Application — Joystick controls should be used when the task requires precise or continuous control in two or more related dimensions. (The term joystick is used here to refer primarily to controls used for cursor placement. Joysticks used in vehicle control (e.g, cyclic sticks) are described herein as levers). When positioning accuracy is more critical than positioning speed, displacement joysticks should be selected over isometric joysticks.

5.4.3.2.3.2 Limb Support — When precise or continuous adjustments are required, limb support shall be provided to conform to the criteria in paragraph 5.4.3.2.1.4.

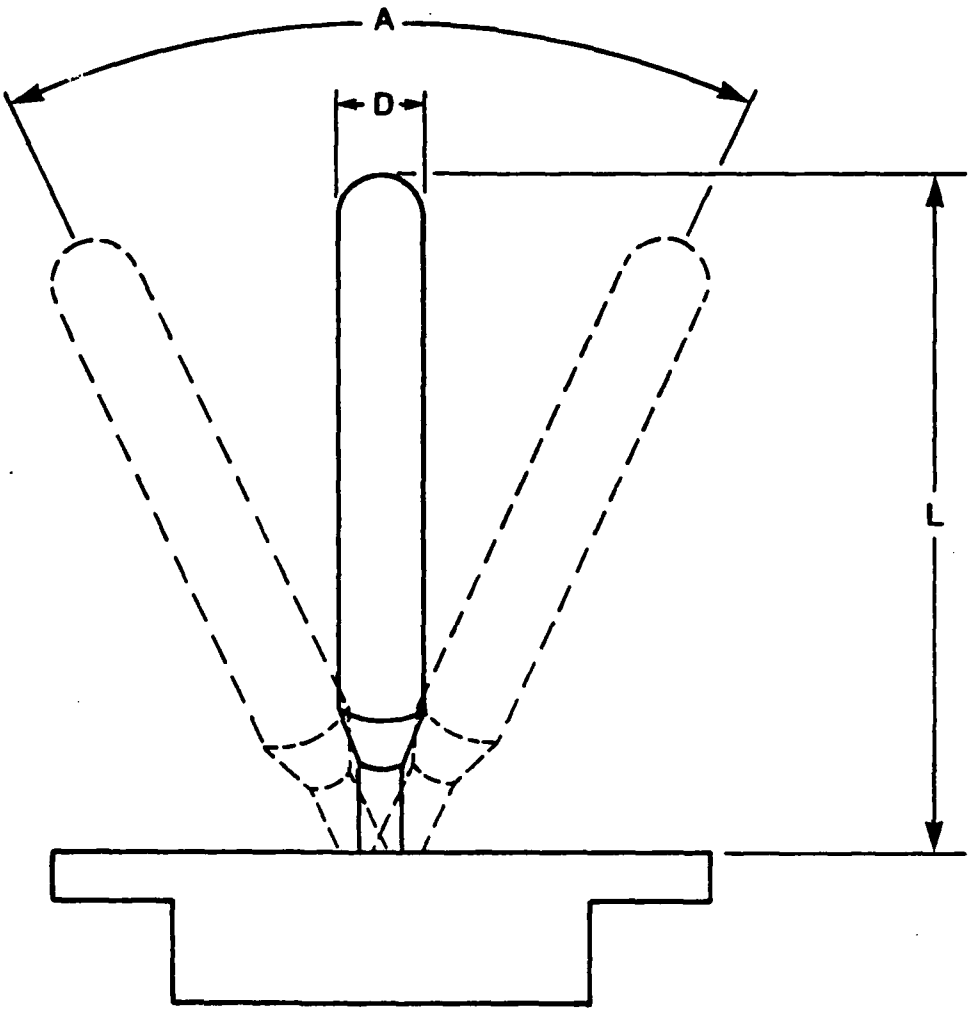
5.4.3.2.3.3 Dimensions, Resistance, and Displacement — Dimensions, resistance and displacement (cone of rotation) for joystick controls shall conform to the criteria in Figure 13a.

5.4.3.2.3.4 Other Requirements —

a. For most applications, joystick controls should be provided with a spring return to center position.

b. The delay between control movement and display response shall not exceed .3 sec.

c. The ratio of the control's displacement to the resulting display movement shall be consistent with the speed and accuracy requirements of the operator.



	DIMENSIONS		RESISTANCE	DISPLACEMENT
	L ARM LENGTH	D DIAMETER		A CONE OF ROTATION
MINIMUM	75 mm (3")	6.5 mm (0.25")	12 oz.	0° *
MAXIMUM	150 mm (6")	25 mm (1.0")	32 oz.	57°
OPTIMUM	— — —	— — —	— — —	5°-20°

* ISOMETRIC (FORCE) JOYSTICK

FIGURE 13-A JOYSTICK CONTROL

d. For precise adjustments in which the operator grasps the joystick "pencil style" below the tip rather than at the tip, the pivot point shall be recessed below the surface on which the wrist rests.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Limb Support, dimensions, displacement, resistance, and spring return: Farrell and Booth (1975) (A-43)

Cone of rotation: Kubokawa and Woodson (1969); Farrell and Booth (1975)

Response delay: AIR Data Store

Control/display movement ratio: Van Cott and Kinkade (1972)

Pivot point: AFSC DH 1-3

5.4.3.2.4 Trackball Controls —

5.4.3.2.4.1 Application — Trackball controls may be used in place of joysticks for functions requiring precise or continuous control in two or more related dimensions. The use of trackball controls should be avoided when associated operator action (e.g., actuate, engage, etc.) is required, since the resulting design would, of necessity, require two-handed operation.

5.4.3.2.4.2 Limb Support — When trackball controls are used to make precise or continuous adjustment, wrist and/or arm support shall be provided.

5.4.3.2.4.3 Diameter — Trackball control diameter shall be not less than 75mm (3") and not greater than 100mm (4").

5.4.3.2.4.4 Resistance — The resistance of the trackball shall be sufficient to preclude inadvertant activation from vibration, movement, etc., in the expected use environment. Resistance shall not exceed 3.0oz, and is preferred to be 1.2 oz.

5.4.3.2.4.5 Surface Velocity — The trackball should be capable of achieving a surface velocity of approximately 28.0 in/sec.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Limb support: Technical review committee

Diameter and resistance: Farrell and Booth (1975) (A-46)

Surface velocity: Rogers (1963)

5.5 Labeling —

5.5.4.6 Label Background —

Recommended Change — Revise first sentence to read: "Label background color shall contrast with the equipment background specified in 5.7.9."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — Lamps: Human Engineering Design Document (1978)

5.5.6.2 Controls and Displays —

5.5.6.2.4 Location —

Recommended Change — Add new provision: "The labeling of concentric controls shall consist of a hierarchy provided by a small solid dot, a larger circle, and a still larger broken circle adjacent to the panel nomenclature for the smallest to largest knob, respectively."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Lamps: Human Engineering Design Document (1978)

Recommended Change — A new section is required to present design criteria for special devices that cannot be encompassed under existing categories (i.e., components used to meet unique operational and/or environment requirements). The following paragraphs are recommended for inclusion in such a section.

5.15 Special Devices — (New Paragraph)

5.15.1 General — Special devices used to meet unique operational and/or environmental requirements shall be designed to optimize human efficienty, safety, and comfort within the constraints imposed by system requirements.

5.15.2 Night Vision Devices —

5.15.2.1 General — Consideration shall be given to designing or selecting night vision devices compatible with the capabilities and limitations of the human visual system.

5.15.2.2 Field Of View — The horizontal field of view (FOV) for night vision devices shall be the maximum obtainable given existing resolution requirements. At a minimum, the FOV shall be 40° for helmet-mounted or goggle-type devices, and 60° for panel-mounted devices.

5.15.2.3 Resolution — For night vision devices employing CRT displays, the minimum resolution shall be 875 TVL for helmet-mounted devices, and 1023 TVL for panel-mounted devices.

5.15.2.4 Frame Rate — Frame rate shall not be less 25Hz.

5.15.2.5 Magnification — For most applications, the use of magnification should be avoided.

5.15.2.6 Signal-to-Noise Ratio — Signal-to-noise ratio for displayed imagery shall not be less than 6.5:1.

5.15.2.7 Other Requirements —

a. Night vision devices employing image intensifier tubes shall have some method of automatic dampening to preclude exposure of the operator to potentially hazardous light levels (i.e., luminance shall not be capable of exceeding 10,000,000 mL).

b. Night vision devices which are designed to be worn by the operator shall be padded to minimize discomfort. The devices shall be designed to accommodate the 5th to 95th percentiles of the expected user population along the following dimensions:

1. Bizygomatic (face) breadth
2. Interpupillary breadth
3. Frontal breadth
4. Nasal breadth
5. Nasal root breadth
6. Nose length
7. Nose protrusion

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — FOV: Johnson, et al. (1977); Sanders, et al. (1975); Holmes (1974); Stich (1974) (A-55)
Resolution: Stich (1974) (A-55)
Frame Rate: Holmes (1974) (A-55)
Magnification: Stich (1974)(A-55)
Singal to Noise Ratio: Humes, et al. (1968) (A-55)
Other Requirements: Technical Review Committee

5.15.3 Head-Up Displays —

5.15.3.1 General — Consideration shall be given to designing or selecting head-up displays compatible with the capabilities and limitations of the human visual system. Information presented on head-up displays shall be limited to critical data which the operator is required to monitor while simultaneously performing some primary visual task.

5.15.3.2 Symbol Brightness — Symbols shall be bright enough to be legible under all expected ambient illuminance. At a minimum, symbol brightness shall be 1,500 ft-L when legibility in direct sunlight (10,000 ft-L) is required. For most high ambient applications, optimal symbol brightness is 2,000-3,000 ft-L.

5.15.3.3 Contrast Ratio — Sufficient contrast shall be provided to ensure symbol legibility under all expected viewing conditions. Specific contrast ratios will vary depending on display medium; however, a minimum contrast ratio of 20% shall prevail.

5.15.3.4 Field Of View — Head-up displays shall have a minimum field of view of approximately 20° in the vertical plane, and 30° in the horizontal plane.

5.15.3.5 Exit Pupil — Head-up displays shall have a minimum exit pupil of 72mm (2.8 in.).

5.15.3.6 Refresh Rate — Head-up displays shall have a minimum refresh rate of 60 Hz.

5.15.3.7 Symbol Line Width — Symbols used in head-up displays shall have a minimum line width of 0.5 milliradians. For most applications, symbol line width of 0.9-1.5mr is considered optimal.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Symbol Brightness: Jenney, et al. (1971) (A-56)
Contrast Ratio: Kelley, et al. (1965); Egan and Goodson (1978) (A-57)
Field of View: Jenney, et al. (1971); Egan and Goodson (1978); MIL-D-81641 (A-59)
Exit Pupil: Van Cott and Kinkade (1972) (A-59)
Refresh Rate: Ketchell and Jenney (1968) (A-60)
Symbol Line Width: Vanderkolk, et al. (1977); Egan and Goodson (1978) (A-60)

Recommended Change — A new section is required to provide guidance in the area of the human-computer interface and dialog. The following paragraphs are recommended for inclusion in this section.

5.16 Human - Computer Interface and Dialog —

5.16.1 Display Format —

5.16.1.1 General — Computer-assisted displays shall be formatted in a manner consistent with the task requirements of the human operator. Data fields, titles, messages, etc., shall be formatted in a logical, consistent manner such that their meanining and inter-relationships are readily discernable to the operator.

5.16.1.2 Data Presentation — Data shall be presented to the operator in a readily usable and readable format. Requirements for transposing, computing, interpolating, or mental translation into other units or numerical bases shall be avoided. When practicable, data shall be presented to conform to the following:

a. Illustrations shall be used whenever possible to supplement or exemplify text.

b. When five or more digits and/or alphanumerics are displayed, and no natural (i.e., population stereotyped) organization exists, characters shall be grouped in blocks of 3 to 4 characters each. Groups shall be separated by a minimum of one blank character.

c. When data fields contain a naturally occurring order (e.g., chronological), such order shall be reflected in the organization of the field.

d. Identical data shall be displayed in a consistent, standardized manner, irrespective of their module of origin.

e. Tasks involving counting shall commence with the number "one," tasks related to measuring shall start with zero.

f. Numbers shall be used as designators when listing selectable items.

g. Lists shall be vertically aligned and left-justified. Indentation should be used for subclassifications.

h. Data which must be scanned and compared shall be presented in tabular or graphic form.

i. The use of hyphenation shall be minimized.

j. When presented in tabular form, alphanumeric data shall be left justified; numeric data shall be right justified by decimal point.

k. Periods shall be placed after item selection numbers, at the end of a sentence, and where necessary for clarification.

l. The use of contractions or shortened forms of words shall be avoided.

m. Each individual field shall be labeled. The operator should not have to rely on contextual cues to identify a field.

n. The following standardized fields shall be used:

- Telephone Number: 914-555-1212
- Time: HH:MM:SS, HH:MM, MM:SS:(.S)
- Date: MM:DD:YY

o. Where lists extend over more than one display page, the last line of one page shall be the first line on the succeeding page.

5.16.1.3 Highlighting — Highlighting shall be used when a particular data item or message is critical to operator decision or action requirements. The following methods of highlighting are acceptable:

a. Contrast enhancement — (i.e., dual level illumination)

b. Blinking — rate between 2-3Hz, with a minimum flash duration of 50 msec

c. Inverse video

d. Graphics — (i.e., the use of highlighting symbology, such as arrows, asterisks, boxes, underlining, etc.)

In all cases, highlighted messages shall provide sufficient figure-ground contrast to ensure prompt operator recognition consistent with the temporal constraints of the task in question.

5.16.1.4 Screen Layout and Structuring — Screen layout and structuring shall be designed to minimize operator scanning and reading requirements, and to minimize the probability of operator error. When practicable, screen layout and structuring shall conform to the following:

a. Displayed data shall be organized in a logical, consistent manner, reflecting some obvious and inherent quality of the data groups (e.g., hierarchical or sequential relationships).

b. Physical location of specific data groups on the screen shall be consistent throughout the operation of the system, irrespective of the module or program in use.

c. Screen layout and separation shall be made apparent to the operator through the use of blank spaces, lines, or some other form of visible demarcation.

d. Lists of options shall be organized according to the probability of selection for each item, with high probability items presented first.

e. Non-option lists or lists of equal-probability options shall be presented in alphabetical or numerical order.

f. Text paragraphs shall be separated by at least one blank line.

g. Formats shall be organized to minimize positioning movements of the cursor.

h. Selection numbers shall be separated from text descriptors by at least one blank space.

i. Items contained in a numbered list and described on "continue" pages shall be numbered relative to the first number on the first page of the list.

j. When directions to the operator accompany a list of options, such directions shall precede presentation of the list.

k. Critical messages requiring immediate operator response shall be highlighted, and, when practicable, placed in the center of the operator's field of view relative to the display or window.

l. The size of the selectable area for an operator option shall encompass, at a minimum, the alphanumeric string of the option designator.

5.16.2 Frame Content —

5.16.2.1 General — Frame content shall be limited to that information required by the operator for a specific action or decision.

5.16.2.2 Feedback — Feedback shall be provided to the operator to indicate the status of system functioning. When practicable, feedback shall conform to the following:

a. When a displayed message or datum is selected as an option or input to the system, the subject item shall be highlighted to indicate acknowledgement by the system.

b. When system functioning requires the operator to standby, periodic feedback shall be provided the operator to indicate normal system operation.

c. When a process or sequence is completed by the system, positive indication shall be presented to the operator concerning the outcome of the process and the requirements for subsequent operator actions.

d. If the system rejects an operator input, feedback shall be provided to indicate the nature of the problem and the required corrective action.

5.16.2.3 Labeling — Each individual data group or message shall contain a descriptive title, phrase, word or similar device to designate the content of the group or message. Where practicable, labeling shall conform to the following:

a. Labels shall be located in a consistent fashion adjacent to the data group or message they describe. The relationship of the label to the group or message being described shall be unambiguous.

b. Labels shall be highlighted or otherwise accentuated to facilitate operator scanning and recognition. The technique used to highlight labels shall be easily distinguished from that used to highlight emergency or critical messages.

c. Labels shall reflect some characteristic common to the group or message being designated. Labels shall be sufficiently unique to preclude operator confusion.

d. When presenting a list of operator options, the label shall reflect the question being posed to the operator.

5.16.2.4 Messages — Messages shall be concise and unambiguous, providing the operator with the information necessary to complete a specific action or decision sequence. When practicable, messages shall conform to the following:

a. Information contained in a message shall be necessary, complete and readily usable. Messages which require the operator to reference external data sources or translate message content shall be avoided.

b. Messages shall contain adequate feedback to the operator to indicate that operator choices or actions have been accepted.

c. Messages containing the digits 0-9 shall be organized in 3x3+1 matrix, with zero centered at the bottom, similar to the telephone keypad.

d. Critical information shall be presented at the beginning of the message.

e. Information required for the next operator entry shall be placed at the end of the message.

f. The terminal's output speed should approximate the mean reading speed of the expected user population. Capability for adjusting output speed should be provided.

g. Messages shall be restricted to factual and informative data. No attempts at humor, sarcasm or other irrelevant modes of presentation shall be made, unless specifically requested by the procuring activity.

5.16.2.5 Interframe Considerations — Interframe design shall minimize the requirements for operator memory. When practicable, interframe design shall conform to the following:

a. When frames are organized in a hierarchical fashion, containing a number of different paths through the series, a visual audit trail of the choices made shall be available upon operator request.

b. When the operator is forced to scroll on a large logical frame, the present and maximum locations shall be presented on the viewable portion of the frame (e.g., line 62 of 112).

c. The operator shall be capable of controlling the amount, format and complexity of information being displayed by the system (e.g., core dumps, program outputs, error messages, etc.)

d. When text is presented in the form of prose, upper and lower case letters shall be used consistent with established orthographic principles, except in cases requiring accentuation (e.g., labels).

e. All data relevant to a specific operator entry shall be displayed on a single frame. Requirements for operator recollection of data between frames shall be avoided.

f. The meaning and context of technical words or phrases shall be consistent between frames.

g. A message occurring in more than one frame shall maintain a constant physical location on the screen. If the message is a variable option list, common elements shall maintain their physical relationship to other recurring elements.

h. Data, text, formats, etc., which have been designated as essential to system performance shall be under system control. Voluntary compliance by the operator shall be avoided.

5.16.3 Command Language —

5.16.3.1 General — Command language shall be written in a logical, consistent manner reflective of the vocabulary and syntax of the expected user population.

5.16.3.2 Abbreviations — Abbreviations shall be used whenever possible to minimize operator input requirements. The use of abbreviations for output shall be avoided. When practicable, abbreviations shall conform to the following:

a. If the operator is using a synonym or abbreviation for a system command name, the system should use the same synonym or abbreviation when referring to that command in messages, prompts, etc., to the operator.

b. Critical operator inputs, responses or actions, in which an error could significantly degrade system performance, shall not be dependent on a single keystroke.

5.16.3.3 Prompting and Structuring — As required, the system shall contain prompting and structuring features designed to request additional or corrected information when an error is detected, and to provide orientation to the operator throughout all interactive sessions. When practicable, prompting and structuring shall conform to the following:

a. When operating in special modes, the system shall display the mode designation and the file(s) being processed.

b. When requesting input from the operator, the system shall prompt the operator in such a manner as to minimize operator input requirements.

c. The system shall be designed to permit correction of individual errors without requiring re-entry of correctly entered data.

d. The system shall contain an historical file of operator entries, in sequence, available upon operator request.

e. Before processing any operator requests which would result in extensive, final and permanent changes to existing data, the system shall display the potential implication of such changes, and require operator acknowledgement.

f. Nomenclature shall be constant for similar or identical functions across components, tasks, and roles for command names, subcommand names, and parameters.

g. Work activities shall be programmed in a closed loop, requiring the operator to issue an explicit command in order to exit.

h. Sign-on processes shall be designed to require minimum input from the operator.

i. Command language shall reflect the operator's point of view, not the programmer's.

j. The system shall be designed to provide hard copy of any frame upon user request. If the copy will be printed remote to the operator, a print confirmation or denial message shall be displayed. Print operation shall not permanently alter screen content.

5.16.4 Recovery Procedures —

5.16.4.1 General — The system shall contain recovery procedures which assist the operator in correcting system-detected errors.

5.16.4.2 Error Messages — The system shall be designed to recognize and report detectable errors. When practicable, error messages shall reflect the following considerations:

a. Feedback — Displayed indication shall be provided which describes the type and location of the error.

b. Directional Guidance — Error messages shall contain instructions to the operator regarding required corrective action.

c. Temporal and Spatial Proximity — Error messages and prompting shall be displayed adjacent to the affected data field as quickly as possible.

d. Corrective Action — Capability shall be provided to the operator to immediately rectify detected errors. This capability shall permit the operator to address the error individually without affecting adjacent entries.

5.16.5 Operator Entry Techniques —

5.16.5.1 General — The design of operator entry techniques shall be compatible with the operational and temporal performance requirements of the operator.

5.16.5.2 Hardware Control Methods —

5.16.5.2.1 Keyboards — Keyboards shall conform to paragraph 5.4.3.1.3, unless otherwise specified by the procuring activity.

5.16.5.2.2 Light Pens —

5.16.5.2.2.1 Application — Light pens may be used when rapid, relatively imprecise input functions are required.

5.16.5.2.2.2 Dimensions — Light pens shall be approximately 12.5mm (0.5 in) in diameter, and 150mm (6.0 in) in length.

5.16.5.2.2.3 Activation — Light pens shall be equipped with a discrete activating mechanism. For most applications, a push-tip switch, requiring 2-5oz. of force to activate, is preferred.

5.16.5.2.2.4 Feedback — Two forms of feedback shall be provided to the operator when using a light pen: (1) feedback concerning light pen placement, preferrably in the form of an illuminated circle projected from the light pen onto the display screen, and (2) feedback that the light pen has actuated and the input received by the system (see 5.16.2.2.a).

5.16.5.3 Cursor Control — Systems employing cursors shall provide cursor control capability consistent with the speed and accuracy requirements of the operator. For most applications, joysticks are the preferred method of cursor control.

5.16.5.4 Entry Mode — The number of required entry modes shall be minimized. Whenever practicable, frames shall be designed to permit the operator to employ a single mode of entry throughout the frame.

5.16.5.5 Selectable Area — The system shall be designed to permit the operator to specify a displayed option by selecting anywhere within the perimeter of the option designator. Selectable areas shall not be contiguous: selectable areas shall be separated by a minimum of two times the width of the selector device.

5.16.5.6 Entry Stacking — When system operation requires the operator to enter a group of logically related entries, the capability for entry stacking shall be provided. A standard character (e.g., slash) shall be designated as an input field separator when using entry stacking.

5.16.5.7 Implicit Prompting — When a fixed length word or collection of characters is to be entered via keyboard, implicit prompting shall be provided in the form of a limited field or special characters (e.g., underscores).

5.16.5.8 Entry Length — Requirements for typed inputs shall be minimized. The length of individual input words (e.g., keywords) should not exceed 5-7 alphabetic characters, and should approximate real words. Whenever possible, numbered option lists and short, meaningful abbreviations shall be used.

5.16.6 Other Requirements —

a. When inserting characters, words or phrases (e.g., editing), items to be inserted shall be collected and displayed in a buffer area of the screen, and then simultaneously inserted by operator command.

b. Data being entered via keyboard shall be displayed, as keyed, on the screen.

c. Mechanical overlays such as coverings over the keyboard or transparent sheets placed on the display should be avoided.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Engel and Granda (1975)
Technical Review Committee

4.0 CONCLUSIONS

The results of the present effort demonstrated a significant requirement for modification to MIL-STD-1472, particularly with regard to design criteria for modern controls and displays, as evidenced by the extent of recommended changes to the standard. This, of course, was the expected outcome of the study, given the dramatic growth in control and display technology which has occurred during the six years since the last update of MIL-STD-1472.

In contrast, requirements for modification to the standard to reduce the incidence of requests for waivers were minimal. This was due to a certain extent to the hierarchial structure of the waiver process which generally results in exemption to a specification as opposed to a standard. Of greater consequence, however, is the absence of a central repository or tracking mechanism for waivers. In some cases, waivers were reportedly held by project officers, in others by the contractor, and in still others, they had been forwarded to a higher command. A survey of test officers at various military installations indicated that requests for waiver to MIL-STD-1472 were, at most, infrequent. This conclusion was supported by an examination of 63 Notices of Exemption (NOE) maintained by the F-18 project. Of the NOEs reviewed, 2 (3%) referenced MIL-STD-1472 as the first tier citation. These exceptions were the result of unique design requirements associated with the F-18 and not an inadequacy in MIL-STD-1472. Given the available data, it was concluded that significant modification to MIL-STD-1472 to reduce the incidence of waiver request was unnecessary.

Of particular interest to the authors were the results of an examination of 56 Equipment Performance Reports (EPRs) issued during the DT II HFE evaluation of the PATRIOT missile system. The results of this review indicated the following problem areas to be of sufficient import to warrant issuance of EPRs:

- Work-platform design
  - 4 incidents involving inadequate handholds and guardrails
  - 5 incidents of inadequate footspace or access
  - 6 incidents involving inadequate non-skid surfaces
  - 1 incident involving inadequate throughway
- 4 incidents of hose/cable reversal due to inadequate coding/keying
- 6 incidents in which procedures were inadequate
- 1 incident of inadequate voice communications (open field)
- Workspace

  - 4 incidents involving physical obstruction to access
  - 1 incident of visual obstruction to display
- 1 incident of incorrect control movement to output
- 1 incident of inadequate contrast in hardcopy printout
- 1 incident of inadequate storage provision
- 1 incident of inadequate platform leveling mechanism
- 1 incident of inadvertent activation due to inadequate switch guarding
- 1 incident involving absence of reset for alarm
- 13 incidents of unnecessary exposure to safety hazards.

The above areas were reviewed to determine if proper application of current 1472 provisions could have elminated or attenuated the problems. The results of the review revealed the following:

- Paragraph 5.7.7.6 describes the requirements for exterior personnel platforms and work areas; however, this provision does not provide adequate guidelines for external work platforms (e.g., radar antenna maintenance, cable hookup on S-280 shelters, particularly with regard to requirements for footspace, location, reach, etc.
- Hose and cable keying are covered under paragraph 5.9.14.4.
- Human factors requirements for written procedures are not addressed in 1472.
- Requirements for voice communication in the open field are not specified in 1472.
- Requirements for physical and visual access to components are adequately covered.

It is the authors' studied opinion that further investigation into the nature of EPRs and similar operational data collected during test and evaluation efforts would reveal additional system inadequacies that are directly relatable to a failure to apply MIL-STD-1472. Such an investigation could result in a more stringent application of MIL-STD-1472, with an ensuing improvement in the human engineering qualities of military systems.

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APPENDIX A

COMPONENT DESIGN REQUIREMENTS AND DATA

Displays
Controls
Special Devices

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
Contrast Ratio	1.4:1			Bennett, 1975, cited in Leysieffer, 1975	Comfortable contrast for viewing a CRT in an airborne environment.
	15 (Acceptable)		30 (Preferred)	Rijnsdorp, 1977	
	15 (i.e., C = 88%)		30 (i.e., C = 94%)	Gould, 1968	
			90%	Meister et al., 1969 Heglin, 1973	
	85%			General Electric, 1961, cited in Ketchel & Jenney 1968	Adequate for most visual tasks.
			50 to 1	Tannas et al., 1978	
Brightness Ratio	2:1 (display:surround)			Meister et al., 1969 Heglin, 1973	
Light/Dark Contrast				Blackwell, 1959, & Shurtleff, 1967, cited in Meister et al., 1969 & Heglin, 1973. Semple et al., 1971	Light symbols on a dark background are recognized more accurately under low ambient lighting. Dark symbols on a light background are recognized more readily under medium and high ambient illumination levels.
Phosphor			D2, V4, V3	Bennett, 1975, cited in Leyseiffer, 1975	Most suitable phosphors for aircraft heads-down displays.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
				Semple et al., 1971	Short persistance phosphors (decay rates less than 10^{-5} sec.) should be used with displays having high regeneration rates of slow image movements. Medium persistance phosphors (decay rates not more than 0.1 sec.) should be used with moderate image movement. Long persistance phosphors (above 0.1 sec. decay time) are best for radar displays where information change is infrequent (30 sec. up to several minutes apart).
			A green phosphor which reduces flicker.	Dickinson, 1979	Since the eye is most sensitive to green, it takes less effort to identify green characters or symbols.
			Best to use phosphors which emit in the middle of the visible spectrum (yellow-green region).	Graham, 1965 & Luckiesh, 1937, cited in Gould, 1968	
	Red symbols on a green background results in the poorest legibility and should be avoided.		Green, yellow, blue or black symbols on a white background.	Burdick et al., 1965	

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
Luminance	80 candela/meter^2 (adequate)		160 candela/meter^2 (preferred)	Rijnsdorp, 1977	
	25mL (Probably adequate assuming adequate contrast)		50mL (preferred)	Gould, 1968	Recommended symbol luminance.
	50 ft-L (acceptable screen luminance)			Meister et al., 1969 Heglin, 1973	
Shades of Gray	7			Miller, 1966; Alluisi, 1957 & Slocum et al., 1967, cited in Ketchell & Jenney, 1968	Slocum et al., did not indicate the empirical grounds for their opinion.
	10			Ketchell & Jenney, 1968	For realistic (commercial) TV images.
			64	Tannas et al., 1978	For good, aesthetic picture quality.
				Johnston, 1968	No reliable differences between 5 & 7 and between 7 & 9 shades of gray. However, on a target recognition task 9 shades of gray result in a significantly greater performance than 5 shades of gray.
Regeneration Rate	50 Hz -- If the illumination is greater than 54 lumens/meter^2 20 Hz -- If the illumination is less than 5.4 lumens/meter^2			Sherr, 1970 cited in Rijnsdorp et al., 1977	

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
			60 frames/sec.	Gould, 1968	For a flicker-free display.
			60 cps	Ketchel & Jenney, 1968	For a flicker-free display.
	30-40 Hz			Meister & Sullivan, 1969	To remove flicker, repetition rate should be at least 50 Hz.
			60 cps	Semple et al., 1971	
			60 cps	Hershberger, 1965	2:1 interlace.
	30-35 Hz			Barmack & Sinaiko, 1966, cited in Meister et al., 1969	Exact rate depends on the display situation, particularly the illumination levels. (For example at 0.01 ft-L, a flicker-free display may be generated at a rate of 20 Hz, but at 100 ft-L, 60 Hz is recommended.
			Above 60 cps	Humes et al., 1968, cited in Levine et al., 1970	The apparent industrial standard of 30 cps may not necessarily be appropriate for military use.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
	Empirically Determined CFF (small fields) (cps) Turnage (1966) Phosphor 10ft-L 32ft-L P-28 34 40 P-19 P-12 25 29 P-7(Y) 32 38 P-1 33 38 P-4(y) 35 41 P-31 37 44 P-20 40 47 * ** Phosphor 50ft-L 100ft-L P-28 31.4 46 P-19 17.5 P-12 32 P-7(Y) 29.8 B,Y 43 P-1 29.2 43 P-4(y) 33.5 B,Y 47 P-31 32.4 51 P-20 32.7 54 * Bryden (1966) **Turnage (1966) Mitchell & Resnick (1960) 10mL 50mL P-1 32 38 P-4(y) 36 43			Gould, 1968	Minimal regeneration rates recommended to prevent flicker for a given phosphor type. Longer persistance phosphors require lower regeneration rates.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
	50 cps acceptable if display brightness drops to 30 ft-L.		60 cps	Poole, 1966, cited in Ketchell & Jenney 1968	For a flicker-free display at luminances up to 180 ft-L.
	30-35 Hz or greater			Meister et al., 1969	Depending on phosphor.
Signal-To-Noise Ratio	7:1			Rosell et al., 1968, cited in Levine et al., 1970	Minimum S/N ratio required for target detection.
			100:1 Performance as a function of S/N ratio and TV lines over target was still increasing at the heighest S/N ratio (100:1) and TV line frequency (11 lines over target)	Levine et al., 1970	Performance varies as a function of the TV lines over target -- S/N ratio interaction. Therefore, any study on the effects of S/N ratio on performance should also include data on TV lines over target.
	6.5:1			Humes et al., 1968, cited in Levine et al., 1970	Performance improved with increases in lines over target and increases in the S/N ratio (up to 6.5/1. The smaller the target the greater the effect of S/N ratio.
	10:1 (satisfactory) 30:1 (good) 50:1 (excellent)			Bogatov, 1966, cited in Meister et al., 1969	

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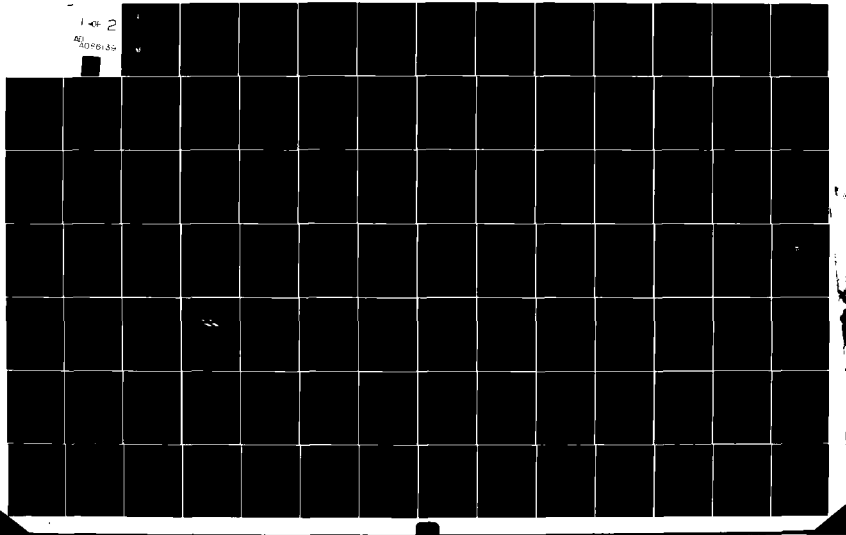

TECHNICAL REPORT RS-CR-80-1

HUMAN ENGINEERING DESIGN CRITERIA FOR MODERN CONTROL/DISPLAY COMPONENTS AND STANDARD PARTS

FINAL REPORT

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FOR

US Army Human Engineering Laboratory Detachment
Systems Engineering Directorate
US Army Missile Laboratory

MAY 1980

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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A study was conducted to identify requirements for modification of MIL-STD-1472B to include human engineering design criteria for modern controls and displays; and to reduce the incidence of requests for waiver of MIL-STD-1472 resulting from unavailability of standard parts. Recommended changes are presented with rationales and references.

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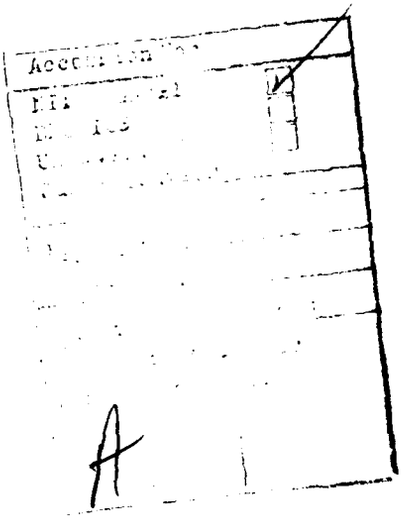
FOREWORD

This report describes the results of the technical effort performed by Essex Corporation under Contract No. DAAK40-79-C-0144.



1.0 INTRODUCTION

MIL-STD-1472 establishes general human engineering criteria for design and development of military systems, equipment, and facilities. The primary objective of human engineering criteria is to provide the designer with specifications and guidelines on design characteristics which have a direct and measurable impact on human performance. Ideally, such criteria are derived from empirical study and are regularly amended to reflect advances in both the human factors discipline and relevant engineering technologies. When properly developed and applied, human engineering design criteria can improve overall system performance in four major areas:

- Operability (reduced workload, error likelihood, and safety hazards)
- Maintainability (reduced downtime)
- Manning (optimized use of the workforce)
- Training (reduced training requirements and skill levels).

Paragraph 1.2 of MIL-STD-1472 states: "The purpose of this standard is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipment, and facility, and achieve effectiveness, simplicity, efficiency, reliability, and safety of system operation, training and maintenance." To effect these objectives, 1472 must achieve the following:

- The criteria must address the range and level of technologies currently being employed in military system development.
- The criteria must be relevant to actual system performance requirements.
- The standard must be responsive to practical constraints imposed by the system acquisition process.
- The content of the standard must be organized and formatted in a manner conducive to its effective application.

This report describes the results of a technical effort conducted by Essex Corporation to improve the adequacy of MIL-STD-1472, primarily in the areas of design criteria for modern control and display components, and to reduce the incidence of waiver requests. The specific objectives of the effort as mandated by the Technical Scope of Work were as follows:

- To incorporate criteria and guidelines for modern control, display, and other operator/maintainer interface hardware into MIL-STD-1472

and thereby enhance application of human engineering into development of military systems, equipment, and facilities

- To reduce or eliminate requests for waivers or exceptions to provisions of MIL-STD-1472 resulting from: 1) unavailability of standard parts or components meeting such provisions; and 2) conflict with other military specifications or standards where differences provide insignificant or marginal human engineering benefit.

The main body of the report is organized into four sections: Introduction, Technical Approach, Results, and Conclusions. In addition, two appendices have been included. Appendix A contains empirical data collected during the study on the various modern components. Appendix B contains tables describing points of conflict between MIL-STD-1472B and other specifications and standards.

2.0 TECHNICAL APPROACH

The technical approach developed to achieve the objectives of the present effort consisted of fourteen iterative tasks partitioned into two phases. The organization of these tasks is depicted in Figure 1.

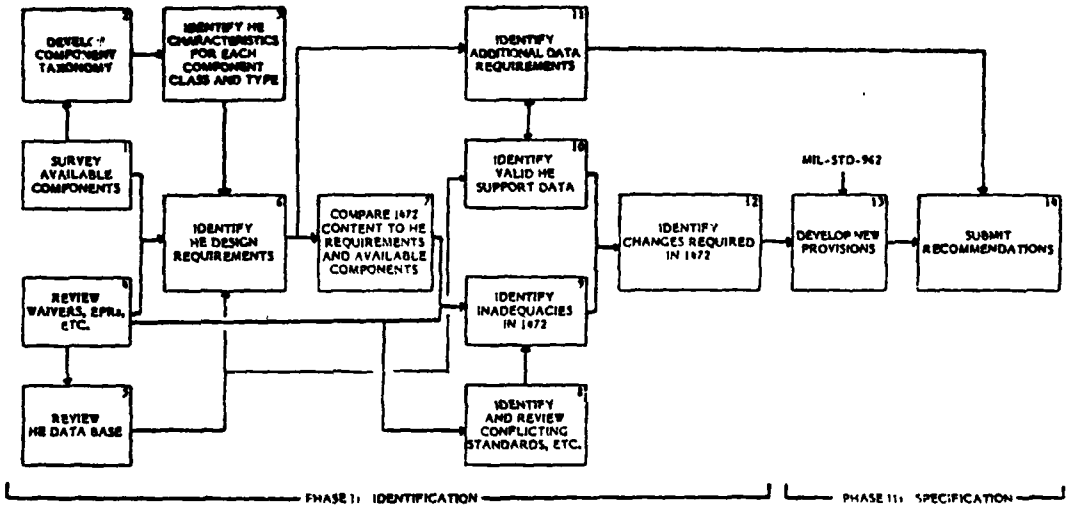


Figure 1: Program Tasks

The content and rationale of each of the tasks are described below.

2.1 Task 1 — Survey Available Components

Purpose — To identify component types currently employed in military systems which require interface with the human operator. This task served as the foundation of the program by ensuring that subsequent efforts focused on components currently used in military system design.

Method — A survey was conducted to identify generic components currently utilized in military design across the services. This task was composed of two concurrent worksteps:

1. Survey of government data sources:
   - Review of DoD Index of Specifications and Standards to identify component types

- Meetings with government procurement specialists
- Survey of human engineering specialists at various military installations.

2. Survey of industry data sources:

   - Review of the Electronic Engineering Master Catalog to identify manufacturers of components which have potential for military application
   - Survey of component manufacturers to acquire data on component specifications.

2.2 Task 2 — Develop Component Taxonomy

Purpose — To organize components identified in Task 1 according to category (i.e., standard or special, and modern or traditional); class (e.g., control); and type (e.g., pushbuttons).

Method — Components identified in Task 1 were organized using the following rationale:

- Categories:
  - standard — components which were military standard, for which a specification was available; or commercial items in general use, manufactured by two or more sources and listed in those companies' catalogs (paragraph 3.1.1 of Technical Scope of Work)
  - special — components not covered by standard definition
  - modern — components, devices, and techniques which are not covered by 1472
  - traditional — components, devices, and techniques which are covered by 1472.
- Classes: generic types of components, with distinguishable functions, initially derived from paragraph titles of 1472 (e.g., controls, displays, covers, fasteners, etc.). Additional classes were defined, as necessary, for modern components.
- Types: subcategories of classes reflecting distinctive design or use characteristics (e.g., toggle switches, rotary controls, tongue-and-slot catches, etc.). Additional types were defined, as necessary, for modern components.

This task focused on organizing identified components in a manner conducive to identifying inherent features relevant to human engineering design criteria.

2.3 Task 3 — Identify Human Engineering Characteristics for Each Component Class and Type

Purpose — To identify the physical and/or operational characteristics of each components class and type which can potentially affect human performance.

Method — Data contained in manufacturer's catalogs were reviewed to identify component characteristics relevant to human engineering. Human engineers specializing in Test and Evaluation of military equipment were surveyed to obtain inputs concerning component problem areas identified in HFE T&E. Baseline human engineering design considerations were derived from TOP 1-2-610 and HEDGE. These considerations were supplemented through a review of the HFE literature describing component characteristics that have been empirically demonstrated to have a significant effect on human performance.

2.4 Task 4 — Review Waivers, EPRs

Purpose — To determine the frequency of requests for waivers to MIL-STD-1472 resulting from: 1) non-availability of components meeting the standard; or 2) conflict with other specifications and standards. To identify action required to reduce the incidence of such waiver requests.

Method — Human engineers specializing in design and evaluation of military systems were surveyed to determine the frequency and nature of waiver requests. Where available, waivers and EPRs were acquired and reviewed to identify problem areas in the content or application of MIL-STD-1472.

2.5 Task 5 — Review Human Engineering Data Base

Purpose — To identify empirical data in the areas of human performance and human engineering and to determine the implications of such data for developing human engineering design criteria applicable to current military systems.

Method — Principal data sources in relevant areas (e.g., human engineering, biomechanics, ergonomics, anthropometry) were reviewed using the Essex computer-based information search and retrieval system. The following data bases were searched:

- NTIS
- ISMEC (Mechanical Engineering)
- COMPENDEX (General Engineering)

- Psychological Abstracts
- INSPEC (Electrical Engineering)

In addition, the Journal of Ergonomics and the Human Factors Journal indexes were reviewed. DDC and NASA STIF data bases were also searched. Human engineers specializing in industrial and military design were surveyed to acquire empirical data not contained in the open literature.

2.6 Task 6 — Identify Human Engineering Design Requirements

Purpose — To identify human engineering design requirements for components currently utilized in military system design.

Method — Components and characteristics identified in previous tasks were reviewed within the context of empirical data on human performance to determine what requirements existed for human engineering design criteria. The focus of this task was directed at isolating those component characteristics which have been empirically demonstrated to significantly affect human performance, primarily in the areas of speed and accuracy of response. These characteristics were then analyzed to determine what design requirements would optimize human performance.

2.7 Task 7 — Compare Content of 1472 to Human Engineering Design Requirements and Available Components

Purpose — To determine how well MIL-STD-1472 addressed the design requirements for available components identified in previous tasks.

Method — The content of MIL-STD-1472 was reviewed to: (1) determine the degree to which the standard provided guidance in the application and design of modern components, and (2) identify provisions which unnecessarily preclude the use of generally available parts.

2.8 Task 8 — Identify and Review Conflicting Standards and Specifications

Purpose — To identify areas of conflict between MIL-STD-1472 and other military standards and specifications which may result in requests for waiver of MIL-STD-1472.

Method — The original intent of this task was to review those standards and specifications which were frequently cited in requests for waiver of MIL-STD-1472 (Task 4). However, since comprehensive waiver history documentation was not available,

a review was conducted of 69 specifications and standards identified as having potential for conflicting with MIL-STD-1472. This review focused on analyzing the qualitative and quantitative provisions of the various specifications and standards to identify variance in design requirements which could result in unnecessary requests for waivers.

2.9 Task 9 — Identify Inadequacies in MIL-STD-1472

Purpose — To identify specific paragraphs in MIL-STD-1472 that fail to meet requirements for designing and/or evaluating the human engineering aspects of military systems currently in operation or under development.

Method — The content of MIL-STD-1472 was compared to data collected in previous tasks to identify areas of inadequacy. This effort focused on the following:

- Provisions in MIL-STD-1472 that fail to adequately address available components
- Provisions that are at variance with empirical data contained in the open literature
- Provisions that unnecessarily preclude the use of standard parts
- Provisions that conflict with requirements of other military specifications and standards.

2.10 Task 10 — Identify Valid Human Engineering Support Data

Purpose — To identify and analyze the human engineering and human performance data necessary to support changes and new provisions in MIL-STD-1472.

Method — Inadequacies in MIL-STD-1472 (Task 9) were compared to empirical data on human engineering and human performance (Task 5) to identify data which could be translated into qualitative or quantitative design criteria. In cases where MIL-STD-1472 conflicted with other military specifications and standards, the data were reviewed to determine the potential impact on human performance of modifying 1472 to conform to the requirements of the other documents.

2.11 Task 11 — Identify Additional Data Requirements

Purpose — To identify design characteristics which have been judged relevant to human performance in the military environment but for which no empirical data are available in the open literature.

Method — Valid human engineering data (Task 10) were compared to the design requirements identified in Task 6 to determine design considerations that could not be objectively resolved from available data. The areas for which existing data were inadequate were analyzed to determine requirements for further research.

2.12 Task 12 — Identify Changes Required in MIL-STD-1472

Purpose — To identify changes required in 1472 in order to: (1) incorporate criteria and guidelines for modern control, display, and other operator/maintainer interface hardware; and (2) to reduce or eliminate problems in meeting 1472 requirements with readily available hardware where such requirements may have marginal human engineering benefit.

Method — The outputs of Tasks 6, 8, 9, and 10 were analyzed to identify changes required to achieve the stated program objectives. The effort concentrated on the following factors:

- Type and degree of change necessary to meet HE design requirements identified in Task 6
- Data available to support change (output of Task 10)
- Rationale for change (projected problems if change is not implemented)
- Projected effect of change in terms of inclusion of modern components and reduction of waiver requests
- Relationship of change to other standards specifications, etc.

2.13 Task 13 — Develop New Provisions

Purpose — To organize and format required changes and support requirements.

Method — Required changes identified in Task 12 were organized and formatted in accordance with MIL-STD-962. The focus of this task was in developing provisions that are not only valid but also usable. To achieve this, emphasis was placed on making the content of a provision directly relatable to the requirements of military design and testing. Additionally, extensive consideration was given to the method of presenting associated support data in a manner conducive to their application. All recommended provisions were evaluated by the Technical Review Committee.

2.14 Task 14 — Submit Final Recommendations

Purpose — To finalize recommendations and to prepare and submit final report.

Method — Draft recommendations were submitted to cognizant technical personnel at the procuring activity for review and comment. Upon acceptance, recommendations were organized into a final report describing their content, rationale, and requirements for implementation. The final technical report was submitted in accordance with Section M, Contract Data Requirements List (DD Form 1423).

3.0 RESULTS

3.1 Phase I

The focus of Phase I was to identify changes required in MIL-STD-1472B to achieve the stated objectives. In terms of the first objectives, criteria for modern control and display components, the results of Phase I indicated a significant requirement for modification of the standard to incorporate design criteria necessary to optimize the human engineering characteristics of modern military systems. With regard to the second objective, reduction of waiver requests, the results of Phase I suggested that the incidence of requests for waiver of MIL-STD-1472 was not sufficient to warrant major modification of the standard. This conclusion, however, is somewhat tenuous due to the dearth of available information concerning request and issuance of waivers.

In organizing this report, the authors have included representative data tabularly in appendix. These appendices are not intended to be exhaustive of the data used in developing recommended changes to MIL-STD-1472B, but rather to provide the interested reader with examples of the data on which such changes were based.

3.2 Phase II

This section presents the results of Phase II of the present study in the form of recommended changes to MIL-STD-1472B. Section 3.2.1 contains recommended changes to paragraph 3.0 (Definitions) of MIL-STD-1472B; Section 3.2.2 contains recommended changes to paragraph 5.0 (Detailed Requirements) of MIL-STD-1472B. Recommended changes to 5.0 (Detailed Requirements) are presented in MIL-STD format, sequenced according to the affected paragraphs of MIL-STD-1472B. Each recommended change is accompanied by a brief description of the rationale for the change, and the references from which the data were extracted. In cases where supporting data are contained in Appendix A, the appendix page number is included.

3.2.1 Definitions

As a result of the expansion in scope of MIL-STD-1472, a number of definitions must be added to paragraph 3.0 of the standard. The following definitions are necessary to explicate recommended changes to the document:

Brightness Ratio — The difference in brightness between the visual task and surrounding field. For projection systems, the brightness ratio is equal to the light output of a projector (measured with no film in the projector) reflected off the screen (image brightness) divided by all the light falling on the screen (measured from the greatest viewing angle) other than that actually forming the image (nonimage brightness); i.e.,

$$BR = \frac{I}{I_n}$$

Contrast — The difference in brightness between two portions of a visual field. When the object (Bmin) is brighter than the background (Bmax), percent of contrast is defined as:

$$\%C = \frac{Bmax - Bmin}{Bmax} \times 100$$

When the background (Bmax) is brighter than the object (Bmin), the following equation is used:

$$\%C = \frac{Bmax - Bmin}{Bmin} \times 100$$

Contrast Ratio — The ratio of maximum luminance to minimum luminance such that:

$$CR = \frac{Bmax - Bmin}{Bmin}$$

For CRT displays, contrast ratio is equal to:

$$C_t = \frac{Bs + Bw}{Bs}$$

where B_s = the brightness of the screen from ambient light, and B_w = the brightness of the written line when ambient light is excluded.

Dot Matrix Display — A flat panel solid-state display which conveys alphanumeric, vector-graphic, or symbolic information through a combination of illuminated dots on a dark background, or V/V.

Electroluminescent Display — A self-illuminated display which emits cold light through the placement of a phosphor substrate in an alternating electrostatic field.

Exit Pupil — That area within a collimated beam in which the entire image formed by an objective lens is capable of being seen.

Field-of-View — The totality of all visual stimuli available to the fixated eye at any given time.

Flicker — A rapid alteration in visual perception induced by a corresponding rapid cyclic change in the intensity of the stimulus. Flicker is measured in terms of a threshold called the critical flicker-fusion frequency, a point at which a flickering stimulus fuses into a continuous one.

Luminance — The amount of light per unit area reflected from or emitted by a surface. It is measured in lumens per unit area per steradian and commonly expressed in foot-lamberts (fL) or millilamberts (mL). 1 fL = 1.08 mL.

Regeneration Rate — (Also referred to as refresh rate or frame rate.) The frequency measured in cycles per second with which a displayed image is updated. Flicker occurs when the regeneration rate of the display is below the critical fusion frequency which in turn depends on the ambient illumination, phosphor persistence, display brightness, bandwidth, volume of information per frame, system storage capacity, and system write/erase speed.

Resolution — The quality of a displayed image and a critical determinant of form recognition which manifests itself in CRT type displays as the number of raster lines per picture height.

Visual Angle — The angle subtended by an object of vision at the nodal point of the eye, usually given in minutes of arc. For angles less than 600 minutes:

$$\text{Visual angle (minutes)} = \frac{(57.3)(60)L}{D}$$

where L = the size of the object measured perpendicular to the line of sight, and D = the distance from the eye to the object.

3.2.2 Detailed Requirements

5.1 Control/Display Integration —

5.1.4 Control Display Ratio —

5.1.4.2 Range of Display Movement —

Recommended Change — Include the following statement: "When a wide range of display element movement is required followed by fine adjustment, a variable gain control should be considered."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Arnold (1977)

5.2 Visual Displays —

5.2.1.2.6 Display Failure Clarity

Recommended Change — Include the following statement: "For warning, caution, or advisory annunciators, the circuitry should be designed to fail-safe the annunciators to the on state should the lighting circuitry experience more than a transient failure."

Rationale — There is presently no recommendation in MIL-STD-1472B which prevents annunciators from being isolated from electrical power should the lighting control circuitry fail. Press-to-test checks (paragraph 5.2.2.1.14) will reveal the failure, but on an intermittent rather than continual basis.

Reference — LAMPS: Human Engineering Design Document (1978)

5.2.1.3.3 Orientation —

Recommended Change — Include the following qualification: "If self-reflection is a problem, perpendicular orientation shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Woodson and Conover (1966)

5.2.1.4 Coding —

5.2.1.4.2 Techniques —

Recommended Change — Rewrite paragraph as follows: "Displays shall be coded by color, size, location, shape, flash rate, alphanumerics, brightness, motion, or inclination, as applicable."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Technical review committee

5.2.1.4.4 Application —

Recommended Change — Add new provision: "If system objectives dictate that the searching, detection, or identification of critical information within a display must be responded to in less than ten seconds, then one or more of the coding techniques outlined in paragraph 5.2.1.4.2 shall be implemented."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-37)

5.2.1.4.5 Color Coding —

Recommended Change — Add new provision: "Color coding should be used when an observer must search for, pick out, or locate one or more characters from a matrix of displayed characters."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Williamson (1978)
Cahill and Carter (1976)
Christ (1975)
Saenz and Riche (1974)
Heglin (1973)
Beyer, et al. (1972)
Munns (1972)
Ketchell and Jenney (1968)
Burdick, et al. (1965)
Smith and Thomas (1964)
Smith (1963)

5.2.1.4.5.1 Choice of Color —

Recommended Change — Add new provision: "No more than five chromatic colors (seven including black and white) shall be used when coding information within a display. The choice of colors shall be in conformance with paragraph 5.4.1.4.5.1, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Cahill and Carter (1976) (A-33)
Burnette, cited in AGARD (1971) (A-33)
Meister and Sullivan (1969) (A-34)
Ketchell and Jenney (1968) (A-33)
Burdick (1965) (A-34)

5.2.1.4.5.2 Size and Spacing —

Recommended Change — Add new provision: "Alphanumeric and geometric or pictorial symbols shall subtend a minimum viewing angle of 20 arc minutes, although 26-30 arc minutes is preferred. To prevent color fusion there should be a spacing of at least three lines between symbols."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-34)
Semple, et al. (1973) (A-35)
Burnette, cited in AGARD (1971)
Burdick (1965) (A-35)

5.2.1.4.5.3 Ambient Illumination —

Recommended Change — Add new provision: "Ambient levels shall be above 0.001 ftC and chromatic illumination should be avoided.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-34)

5.2.1.4.5.4 Contrast —

Recommended Change — Add new provision: "Display contrast for a seven-color system shall be at least 10:1, and preferably between 20-30:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973) (A-34)

5.2.1.4.6 Shape Coding —

Recommended Change — Add new provision: "Shape coding should be used when a viewer must identify one or more objects from a matrix of displayed objects. Shape coding should also be used when the information represented on the display is qualitative in nature and when coding by color is not feasible. A maximum of 15 shapes shall be used, and only 6 under adverse display conditions. To augment object identification, color redundancy should be added. If possible, the symbols shall be associated with the objects they represent. Only simple, symmetrical symbols with enclosed areas and sharp angles or smooth curves should be used. Variations of a single geometric form shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Saenz and Riche (1974)
Heglin (1973) (A-36)
Van Cott and Kinkade (1972) (A-35)
Semple, et al. (1971) (A-35)
Ketchell and Jenney (1968) (A-36)
Smith and Thomas (1964)

5.2.1.4.7 Alphanumeric Coding —

Recommended Change — Add new provision: "Letters and numbers should be used for identification tasks and short code words which represent one of a kind type items. For three-character combinations, a number should be used for the first and third characters, and a letter for the middle character. There is no maximum number of alphanumeric combinations which can be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Christ (1975)
Heglin (1973) (A-37)
Van Cott and Kinkade (1972) (A-37)
Munns (1972)
Ketchell and Jenney (1968)
Smith and Thomas (1964)

5.2.1.4.8 Size Coding —

Recommended Change — Add new provision: "The maximum number of steps which should be used at any given time is three. To insure that the sizes are equally identifiable, the steps should increase on a logarithmic scale."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-37)
Ketchell and Jenney (1968) (A-37)

5.2.1.4.9 Brightness Coding —

Recommended Change — Add new provision: "Brightness coding is not generally recommended, but if used should employ no more than two levels (dim and bright). The higher level should represent items of primary interest with the lower level reserved for background or supplementary information."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Beyer, et al. (1973) (A-37)
Heglin (1973) (A-38)
Van Cott and Kinkade (1972) (A-38)
Ketchell and Jenney (1968) (A-38)

5.2.1.4.10 Motion Coding —

Recommended Change — Add new provision: "Motion coding is not generally advocated, especially for use on head-up displays. (However, if used, no more than two velocities are recommended.")

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Ketchell and Jenney (1968) (A-38)

5.2.1.4.11 Inclination Coding —

Recommended Change — Add new provision: "The angular orientation of lines on a display shall contain no more than 24 inclinations. Where rapid, accurate reading of the display is required, eight inclinations are recommended while four are preferred. The line length should be betweeen 0.2 and 0.3 inches. Intra-line orientation (measured in degrees) shall contain equally spaced deviations."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Heglin (1973) (A-38)
Van Cott and Kinkade (1972) (A-38)

5.2.1.4.12 Flash Coding —

Recommended Change — Include the following statement: "Flash coding shall be in conformance with paragraph 5.2.2.1.19, herein."

5.2.2.1.19 Flashing Lights —

Recommended Change — Rewrite paragraph as follows: "The use of flashing lights shall be minimized. Flashing lights may be used only when it is necessary to call the operator's attention to some condition requiring immediate action. The flash rate shall be in the range between one to five flashes per second, with the on and off phases of about equal duration. No more than three frequencies shall be used, with no more than two, and preferably one blinking signal on the display at any given time. The frequencies should be equally spaced on a logarithmic scale, with the faster flash rates representing the more critical information. The indicator shall be designed such that, if energized and the flasher device fails, the light will illuminate and burn steadily (see 5.3.2.4)."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Van Cott and Kinkade (1972) (A-38)
MIL-STD-1472B (1972)
Ketchell and Jenney (1968) (A-38)

5.2.2 Transilluminated Displays —

5.2.2.1.9 Luminance —

Recommended Change — Include the following statement: "The measured photometric brightness in the visible spectrum shall be 10 fL minimum at rated voltage."

Rationale — Expand to ensure conformance with paragraph 3.5.15 MIL-R-28803.

5.2.2.1.10 Luminance Control

Recommended Change — Include the following statement: "The design of the dimming feature shall be such that when the cap is turned to the full-dim position, a small diffused ring of light will be emitted through the lens."

Rationale — Expand to ensure conformance with paragraph 3.4.3 MIL-L-7961B and paragraph 1.2 of MIL-STD-1472B.

5.2.2.2.3 Lettering —

Recommended Change — Rewrite paragraph as follows: "Lettering should be all capitals, with font style similar to Futura Demibold type or Groton Extended engraving. Numerals should be similar to Futura Medium and Tempo Bold type or Groton Condensed engraving. Letter width-to-height ratio should be 1:1, and shall not be less than 3:5. The stroke width-to-height ratio should be 1:8 to 1:10, and for highly luminous letters, 1:12 to 1:20."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Heglin (1973)

5.2.3.1.4 Linear Scales —

Recommended Change — Include the following statement: "Non-linear scales should be used in situations where it is necessary to condense a large range into a small space in such a way as to permit sensitive readings at certain critical ranges of the scale."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)

5.2.3.1.5.1 Graduations —

Recommended Change — Include the following statement: "Graduation-interval values of 2 are less desirable than values of 1 or 5 and should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)

5.2.3.1.7.3 Mounting —

Recommended Change — Resolve disparity between MIL-STD-1472B and MIL-M-16034A, paragraph 3.5.2.2.1 which states that the clearance between the points index and graduated scale shall not exceed 0.10 inch nor be less than 0.03 inches.

5.2.3.3.1 Numerical Progression —

Recommended Change — Include the following statement: "If possible, displays utilizing moving scales and fixed pointers should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Arnold (1977)
Van Cott and Kinkade (1972)
MIL-STD-1472B (Section 5.1.3.5)

5.2.4 Cathode Ray Tube (CRT) Displays —

This section should be expanded to include the following criteria.

5.2.4.1 Signal Size —

5.2.4.1.1 Alphanumerics —

Recommended Change — Add new provision: "Alphanumeric characters shall subtend not less than 12-15 minutes of visual angle. The characters shall be composed of upper case letters with a resolution of not less than ten lines per symbol height. Flight display alphanumerics shall subtend not less than 24 minutes of visual angle to insure adequate legibility under aircraft environmental conditions."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-9)
Van Cott and Kinkade (1972) (A-10)
Burnett, cited in AGARD (1971) (A-10)
Meister and Sullivan (1969) (A-10)
Ketchell and Jenney (1968) (A-10)
Gould (1968) (A-10)

5.2.4.1.2 Symbology —

Recommended Change — Add new provision: "Geometric and pictoral symbols shall subtend a minimum of 16 minutes of visual angle. For critical targets, or when a target of complex shape is to be distinguished from a non-target shape that is also complex, the target signal should subtend not less than 20 minutes of visual angle with a resolution of not less than 16-17 lines per symbol height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Semple, et al. (1971) (A-10)
Burnette, cited in AGARD (1971) (A-10)
Meister and Sullivan (1969) (A-10)

5.2.4.1.3 Height-to-Width Ratio —

Recommended Change — Add new provision: "The height-to-width ratio for alphanumerics shall be between 7:5 and 3:2. For alphanumerics in an airborne environment, the height-to-width ratio shall be between 2:1 and 1:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-11)
Rijnsdorp and Rouse (1977) (A-11)
Burnette, cited in AGARD (1971) (A-11)
McCormick (1970) (A-11)
Sherr (1970) (A-11)
Meister and Sullivan (1969) (A-11)

5.2.4.1.4 Stroke Width-to-Height Ratio —

Recommended Change — Add new provision: "Stroke width shall be in the range of 1:6 to 1:10 character height, with the thinner width used for light characters on a dark background. For alphanumerics in an airborne environment, the stroke width-to-height ratio should be 1:5."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Burnette, cited in AGARD (1971) (A-12)
Meister and Sullivan (1969) (A-12)
Gould (1968) (A-12)

5.2.4.1.5 Character Separation —

Recommended Change — Add new provision: "Wider spacing between characters shall be used for light symbols on a dark background rather than for dark symbols on a light background. Generally, character separation shall be between 25 and 63% of the symbol height, with the lower limit preferred under low ambient illumination (1.0 fL), or when the visual angle subtended by the characters is less than 16 minutes

of arc. When the illumination level is increased between 20 and 40 fL, character separation should be two times the symbol height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Semple, et al. (1971) (A-12)
Burnette, cited in AGARD (1971) (A-12)
Meister and Sullivan (1971) (A-12)

5.2.4.2 Viewing Conditions —

5.2.4.2.1 Viewing Distance —

Recommended Change — Add new provision: "A viewing distance of 18 inches shall be provided whenever practicable. When periods of scope observation will be short, or where dim signals must be detected, the viewing distance may be reduced to 14 inches. Due to eye strain and fatigue effects, viewing distances of less than 16 inches shall be avoided. The maximum viewing distance for a single seated operator shall be 28 inches, unless the screen size and symbol subtense are adjusted accordingly."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1977) (A-13)
Meister and Sullivan (1969) (A-13)

5.2.4.2.2 Viewing Angle —

Recommended Change — Add new provision: "The optimal horizontal angle for viewing a CRT display is 90° straight-on. No viewer should be seated at a viewing angle smaller than 45° and under no circumstances shall an observer be required to view the display from an angle smaller than 30°."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Van Cott and Kinkade (1972) (A-14)
Burnette, cited in AGARD (1971) (A-13)
Meister and Sullivan (1969) (A-14)

5.2.4.2.3 Display Size —

Recommended Change — Add new provision: "At a 28 inch viewing distance for a single seated operator, the screen size should be 12 inches in diagonal. This applies to both console based CRTs as well as CRTs used in flight control."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-13)
Semple, et al. (1971) (A-13)
Burnette, cited in AGARD (1971) (A-13)

5.2.4.3 Screen Luminance —

Recommended Change — Rewrite paragraph as follows: "The ambient illuminance shall not contribute more than 25% of screen brightness through diffuse reflection and phosphor excitation. A minimal screen luminance of 25mL shall be maintained, with a preferred screen luminance of 50mL. For CRTs used in dark adapted areas, screen luminance should be below 2.2mL. Under low ambient conditions (1.0 fL), light symbols on a dark background shall be used. Dark symbols on a light background shall be used under medium and high ambient illumination levels. A contrast of 88% is recommended while 94% is preferred.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977)
Heglin (1973)
Meister and Sullivan (1969)
Ketchell and Jenney (1968)
Gould (1968)

5.2.4.6 Ambient Illuminance —

Recommended Change — Include the following statement: "In general, the ambient illumination should be maintained at a level below the brightness of the CRT background. The operator should be visually adapted to the level of the scope brightness so as to maximize the visibility of near threshold targets. A pre-exposure duration of 2½ minutes shall be adhered to, if possible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — AFSC DH 1-3

5.2.4.7 Reflected Glare —

Recommended Change — Incorporate Section 5.2.4.8 into this section and rewrite paragraph as follows: "Reflected glare shall be minimized by proper placement of the scope relative to the light source. The light source should not be located within 60° of the viewer's central field-of-view. The light shall be diffused and distributed evenly over the work area, with the ratio between light and dark portions of the work surface not exceeding 7:1. In addition, glare shall be minimized by: proper placement of the scope relative to the light source, through the use of a hood or shield; by optical coatings or filters over the light source; or by directional or spectrum filters. All surfaces adjacent to the CRT shall have a dull matte finish. The reflectances of these surfaces shall be such that the resultant luminances will be consistent with the criteria established above."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Hultgren and Knave (1974)
Heglin (1973)

5.2.4.8 Phosphor —

Recommended Change — Add new provision: "The choice of phosphor depends primarily upon system application, but generally should be one which emits in the green region of the visible spectrum and reduces flicker. Short persistence phosphors (decay rates less than 10^{-3} sec.) should be used with displays having high regeneration rates and slow image movements. Medium persistence phosphors (decay rates not more than 0.1 sec.) should be used with moderate image movement, while the longer persistence phosphors are best for radar displays where information update is relatively infrequent, between 30 seconds and several minutes apart. Red symbols on a green background shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-2)
Semple, et al. (1971) (A-2)
Gould (1968) (A-2)
Burdick, et al. (1965) (A-2)

5.2.4.9 Shades of Gray —

Recommended Change — Change the paragraph on Electronically or Optically Generated Displays to 5.2.4.16 and retitle paragraph 5.2.4.9 to Shades of Gray. Add the following provision: "To insure target recognition and to provide realistic TV images, at least 10 shades of gray should be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Ketchell and Jenney (1968) (A-3)
Johnston (1968) (A-3)

5.2.4.10 Regeneration Rate —

Recommended Change — Add new provison: "The regeneration rate for a particular display depends on a number of variables, but generally shall be above the critical

frequency at fusion such that the occurrence of disturbing flicker is not perceptible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-3)
Semple, et al. (1971) (A-4)
Levine (1970) (A-6)
Meister and Sullivan (1969) (A-4)
Ketchell and Jenney (1968) (A-4)
Gould (1968) (A-5)
Barmack and Sinaiko (1966) (A-4)
Harshbarger (1965) (A-4)

5.2.4.11 Signal-To-Noise Ratio —

Recommended Change — Add new provision: "The signal-to-noise ratio shall be one which is large enough to achieve system objectives. Generally, a signal-to-noise ratio of 10:1 is considered satisfactory, 30:1 is considered good, and 50:1 is considered excellent."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Levine, et al. (1970) (A-6)
Meister and Sullivan (1969) (A-6)

5.2.4.12 Response Time —

Recommended Change — Add new provision: "The time from initiation of computer output until a new CRT page appears on the screen should be no longer than one second and shall not exceed three seconds."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979) (A-14)
Meister and Sullivan (1969)

5.2.4.13 Geometric Distortion —

Recommended Change — Add new provision: "The cumulative effects of all geometric distortion should not displace any point on the screen from its correct position by more than 2-5 percent of picture height."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-15)

5.2.4.14 Graphics —

Recommended Changes — Add new provision: "Lines should be composed of at least 20 points per cm (50 points per inch) to provide the illusion of continuity."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Rijnsdorp and Rouse (1977) (A-15)
Gould (1968) (A-15)

5.2.4.15 Cathode Ray Tube Displays (PPI) — This section on CRTs should be expanded to include PPI type displays.

5.2.4.15.1 Display Size

Recommended Change — Add new provision: "To insure optimal target detection, the display should be 7 inches in diameter for target sizes between 2 and 8mm. For target sizes between 12 and 16mm, the display should be between 12 and 16 inches in diameter."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References -- Semple, et al. (1971) (A-17)
Meister and Sullivan (1969) (A-17)

5.2.4.15.2 Pip Size —

Recommended Change — Add new provision: "The pip shall subtend a visual angle of no less than 20 minutes of arc."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.3 Viewing Distance —

Recommended Change — Add the following provision: "The viewing distance for PPI type displays shall conform to paragraph 5.2.4.2.1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Dickinson (1979)
Van Cott and Kinkade (1972)
Meister and Sullivan (1969)

5.2.4.15.4 Pip Persistance —

Recommended Change — Add the following provision: "The pip shall appear for a minimum of .1 seconds."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.5 Scanning Rate —

Recommended Change — Add new provision: "The scanning rate for a 7-inch screen should be not less than 12 rpm, and preferably higher."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-17)

5.2.4.15.6 Screen Luminance —

Recommended Change — Add new provision: "Screen luminance shall be between 10 and 100 fL, with the higher luminance recommended under brighter ambient conditions."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Meister and Sullivan (1969) (A-18)

5.2.4.15.7 Ambient Illumination —

Recommended Change — Add new provision: "To insure pip detectability, ambient illumination should not be greater than 0.1 fC. If the operator must perform other visual tasks requiring higher brightness levels, the ambient illumination should not be brighter than 100 times the average brightness of the radar scope."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — AFSC DH 1-3
Heglin (1973)

5.2.6 Other Displays —

5.2.6.1 General —

5.2.6.1.1 Types —

Recommended Change — Rewrite paragraph as follows: "Where applicable, direct-reading counters, printers, plotters, flags, optical projection displays, electro-luminescent displays and dot matrix displays should be considered."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.2.6.6 Optical Projection Displays —

5.2.6.6.2 Seating Area —

Recommended Change — Include the following statement: "In order to insure comfort and good visibility, large meeting rooms with folding chairs should provide about 5 to 6 square feet of floor space per person. For smaller rooms with fixed seating, about 10 to 12 square feet of floor space per viewer should be allotted."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Kodak Publication No. S-3 (1978)

5.2.6.6.4.3 Contrast —

5.2.6.6.4.3.1 Brightness Ratio —

Recommended Change — Delete paragraph 5.2.6.6.4.3 and add new provision: "Under optimal ambient conditions, the brightness ratio for optically projected displays should be 500:1. The minimum brightness ratio for viewing charts, printed text, and other linework via slides or opaque projectors shall be 5:1. For projections which are limited in shadows and detail, such as animation and photographs with limited brightness range, the minimum brightness ratio shall be 25:1. For images which show a full range of colors (or grays in black-and-white photographs), the minimum brightness ratio shall be 100:1."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Kodak Publication No. S-3 (1978) (A-22)
Heglin (1973) (A-22)
IES Lighting Handbook (1972)

5.2.6.6.4.3.2 Direction of Contrast —

Recommended Change — Add new provision: "Contrast may be either light on a dark background or vice-versa, except where superposition is used. For subtractive superposition (at the source), data shall be presented as dark markings on a transparent background. For additive superposition (at the screen), data shall be presented as light markings on an opaque background. Colored markings against colored backgrounds of comparable brightness shall be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-STD-1472B (1974)
Heglin (1973) (A-23)
Van Cott and Kinkade (1972) (A-23)

5.2.6.6.5 Rear Projection —

Recommended Change — Add new provision: "Rear projection screens shall be used in those situations in which there are physical obstructions to front projection resulting in poor visibility, or in work areas requiring high ambient illumination for other activities. Under high ambient conditions, the projected image should be no more than 20 to 30 inches wide."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Kodak Publication No. S-3 (1978)
Van Cott and Kinkade (1972)

5.2.6.7 Light Emitting Diodes (LEDs) —

5.2.6.7.1 General —

Recommended Change — Rewrite paragraph as follows: "In general, the standard for LEDs will be the same as the requirements for Transilluminated Displays, paragraph 5.2.2 and Dot Matrix Displays, paragraph 5.2.6.8, unless specified below."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Technical Review Committee

5.2.6.8 Dot Matrix Displays —

5.2.6.8.1 General —

Recommended Change — "The design criteria listed below shall be applied to those flat panel (light emitting diodes, liquid crystal, CRT, and gas discharge) displays used exclusively for the presentation of alphanumeric and symbolic information."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

5.2.6.8.2 Application —

Recommended Change — Include the following paragraph "Dot matrix displays are excellent for applications involving interactive computer systems since they are capable of providing a capacious information interface between the man-computer system. Dot-matrix displays are also suitable for use in instruments, avionics, navigation and communication equipment where the presentation of alphanumeric, vector-graphic, symbolic or real-time information is required."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Technical Review Committee
Snyder and Maddox (1978)

5.2.6.8.3 Symbol Definition —

Recommended Change — Add new provision: "The smallest symbol definition for a dot mosaic shall be 5x7, with a 7x9 mosaic being preferred. If system requirements call for symbol rotation, a minimum definition of 8x11 is required, and 15x21 preferred. For stroke mosaics, 16 and 23 segment fonts should be used in preference to 17, 27 or 38 segment fonts."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Scanlan and Carel (1976) (A-29)
Vanderkolk, et al. (1975) (A-29)
Meister and Sullivan (1969)

5.2.6.8.4 Symbol Subtense —

Recommended Change — Add new provision: "Alphanumeric characters shall subtend not less than 12 minutes of visual angle, and preferably not less than 16 minutes. Flight display alphanumerics shall subtend not less than 24 minutes of visual angle."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Vanderkolk, et al. (1975) (A-29)

5.2.6.8.5 Viewing Angle —

Recommended Change — Add new provision: "The viewing angle for dot matrix displays shall conform to paragraph 5.2.4.2.2, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Vanderkolk, et al. (1975) (A-28)
Van Cott and Kinkade (1972)

Burnette, cited in AGARD (1971)
Meister and Sullivan (1969)

5.2.6.8.6 Emitter Characteristics —

5.2.6.8.6.1 Size —

Recommended Change — Add new provision: "The optimum emitter size depends upon the particular task. A 0.75mm dot should be used for reading tasks and a 1.5mm dot should be used for search tasks. If the display is to be used for both types of tasks, the dot should be between 1.0 and 1.2mm."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Scanlan and Carel (1976)

5.2.6.8.6.2 Spacing —

Recommended Change — Add new provision: "A dot spacing/size ratio of 0.5 should be adhered to, if possible."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Snyder and Maddox (1978) (A-29)

5.2.6.8.6.3 Shape —

Recommended Change — Add new provision: "Either circular or square emitters shall be used."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — Snyder and Maddox (1978) (A-29)
Vartabedian (A-29)

5.2.6.8.6.4 Color —

Recommended Change — Add new provision: "Monochromatic matrix displays shall use the following emitter colors: In order of preference; green (555mu), yellow (575mu), orange (585mu), and red (660mu). Blue emitters should be avoided."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Vanderkolk, et al. (1975) (A-28)

5.2.6.8.7 Luminance —

Recommended Change — Add new provision: "The minimum screen luminance shall be 21mL. A contrast ratio of at least 8.5:1 should be provided, if possible."

Rationale —Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Snyder and Taylor (1979) (A-28)
Snyder and Maddox (1978) (A-28)

5.2.6.8.8 Regeneration Rate —

Recommended Change — Add new provision: "The regeneration rate shall conform to paragraph 5.2.4.10, herein."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Riley (1977) (A-29)
Scanlan and Carel (1976) (A-29)

5.2.6.9 Electroluminescent Displays —

5.2.6.9.1 General —

Recommended Change — Include a section entitled Electroluminescent Displays and add the following provision: "Electroluminescent display resolution shall be equivalent to that recommended for CRT type displays as outlined in paragraphs 5.2.4.1.1 and 5.2.4.1.2. Symbol definition will be the same as that recommended for stroke mosaic font, paragraph 5.2.6.8.3. If the display will be used in an airborne environment, the information displayed shall be of sufficient contrast and brightness to be seen in up to 10,000 foot candle ambient conditions. Additional design, safety and human engineering requirements shall be accomplished in conformance with MIL-STD-884, MIL-STD-454, MIL-H-46855, and 5.2.2 herein."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Van Cott and Kinkade (1972)
King, et al. (1970)
Ciuffini (1966)
MIL-STD-884
MIL-STD-454
MIL-H-46855

5.2.6.9.2 Application —

Recommended Change — Include the following paragraph: "Electroluminescent displays can be used wherever system requirements dictate the use of transilluminated displays. In addition, they can replace existing mechanical instrumentation while offering the following advantages: conservation of instrument panel space, lighter weight, lower power requirements, lack of heat production, uniform distribution of illumination, longer life, elimination of parallax and display flexibility. Electroluminescent displays should also be used for those applications in which a sudden failure of a lamp could result in catastrophic consequences (See 5.2.2.1.13)."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Reynolds (1971)
King, et al. (1970)
Frost and Hoffman (1968)
Peterson and Smith (1966)
Stenson (1966)

5.4 Controls —

5.4.1 General Criteria —

5.4.1.1 Selection —

Recommended Change — Add new paragraph, 5.4.1.1.5, Continuous-Adjustment Controls - Continuous-adjustment controls shall be used when precise adjustments along a continuum are required, or when a large number of discrete settings (more than 24) is needed.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Van Cott and Kinkade (1972)

5.4.1.1.4 Detent Controls —

Recommended Change — Retitle paragraph to read "Discrete-Adjustment (Detent) Controls —"

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — Arnold (1977)

5.4.1.1.4 Detent Controls —

Recommended Change — Include the following statement: "Detent controls shall not be used for automated functions, for increasing-decreasing functions, or for those circumstances requiring momentary positioning."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — MIL-STD-454F

5.4.1.2 Direction of Movement —

5.4.1.2.3 Operator-Control Orientation —

Recommended Change — Expand paragraph to include: "Vehicle operator stations shall be designed to permit the operator to face in the direction of primary vehicle movement when operating controls effecting vehicle movement."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Arnold (1977)

5.4.1.3 Arrangement and Grouping —

5.4.1.3.1 Grouping —

Recommended Change — Expand the paragraph to include the following: "When multi-function controls are used, related functions shall be grouped together within and between modes."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee.

5.4.1.4 Coding —

5.4.1.4.3 Size-Coding —

Recommended Change — Expand the paragraph to include the following: "When knob diameter is used as the coding parameter, differences between diameters shall not be less than 13mm (0.5 in.). When knob thickness is the coding parameter, differences between thicknesses shall not be less than 10mm (0.4 in.).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Bradley, cited in Arnold (1977)

5.4.1.4.4 Shape Coding —

Recommended Change — Expand the paragraph to include the following: "If possible, the shapes chosen shall be associated with or resemble control function."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Van Cott and Kinkade, cited in Arnold (1977)

5.4.1.8 Prevention of Accidental Activation —

5.4.1.8.4 Methods —

Recommended Change — Add new provision, h, "When software is involved, provide guarding by requiring concurrent or consecutive switch activations."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.4.2 Rotary Controls —

5.4.2.1.1.5 Contrast —

Recommended Change — Rewrite paragraph as follows: "A reference line shall be provided on rotary switch controls. The contrast of the reference line to the skirt shall not be less than 2.5 for gray panels and 9 for black panels, when determined as specified in MIL-P-7788."

Rationale — Avoid conflict with MIL-K-25049 and MIL-P-7788.

Reference — MIL-P-7788 and MIL-K-25049

Note — MIL-P-7788 presents the following formula for contrast (C):

$$C = \frac{B_2 - B_1}{B_1}$$

where B_1 is background brightness and B_2 is the brightness of the marking.

5.4.2.1.1.7 Dimensions, Resistance, Displacement, and Separation — (Figure 3).

Recommended Change — Under "Displacement" a minimum of 15^{o} should be specified for controls where visual positioning is possible; 30^{o} minimum displacement should be required for tactually positioned controls.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3 (1977)

5.4.2.1.1.7 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Under "Dimensions" the minimum width should be .25 inch.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3 (1977)

5.4.2.1.3 Thumbwheel Controls —

5.4.2.1.3.8.2 Continuous Thumbwheel Controls —

Recommended Change — Add the following statement: A detent shall be provided for thumbwheel controls having an off position.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Farrell and Booth (1975)

5.4.2.1.3.9 Separation — (Figure 5).

Recommended Change — Change minimum separation requirement to 6.5mm (.25 in.). Add preferred separation of 9.5mm (.375 in.).

Rationale — Avoid conflict with MIL-STD-803, and reflect empirical data on human performance.

LOAD	SPECIFICATION	HANDLE				TURNING RADIUS			
		LENGTH		DIAMETER		RATE BELOW 100 RPM		RATE ABOVE 100 RPM	
		mm	in.	mm	in.	mm	in.	mm	in.
LIGHT LOADS: Less than 2.27kg (5 lb) (Wrist and finger movement)	MINIMUM	25.4	1	9.525	3/8	38.1	1½	12.7	1/2
	PREFERRED	38.1	1½	12.7	1/2	76.2	3	57.15	2½
	MAXIMUM	76.2	3	15.875	5/8	127.0	5	114.3	4½
HEAVY LOADS: More than 2.27kg (5 lb) (Arm movement)	MINIMUM	76.2	3	25.4	1	190.5	7½	127.0	5
	PREFERRED	95.25	3¾	25.4	1	--	--	--	--
	MAXIMUM	--	--	38.1	1½	508.0	20	228.6	9

Figure 7a. Continuous Adjustment Cranks

Reference — AFSC-DH 1-3 (1977)
Van Cott and Kinkade (1972)

5.4.2.1.3.9 Separation —

Recommended Change — Change minimum diameter to 25.4mm (1.0 in.) and maximum diameter to 76.2mm (3.0 in.).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — MIL-C-81774

5.4.2.2.2 Cranks —

5.4.2.2.2.3 Dimensions, Resistance, and Separation —

Recommended Change — Crank dimensions, resistance, and separation shall conform to the criteria in Figure 7a.

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — AFSC DH 1-3
Arnold (1977)

5.4.3 Linear Controls —

5.4.3.1 Discrete Linear Controls —

5.4.3.1.1 Pushbuttons (Finger- or Hand-Operated) —

5.4.3.1.1.4 Channel or Cover Guard —

Recommended Change — Include the following statement: "When the guard is in the open position, its location shall not interfere with the operation of the protected device or adjacent controls."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-C-81774A, paragraph 3.4.2
LAMPS: Human Engineering Design Document (1978)

5.4.3.1.1.5 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Add the following statement: "When rectangular pushbuttons are used, dimensions, resistance, displacement, and separation between adjacent edges of pushbuttons shall conform to the criteria in Figure 12."

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee

5.4.3.1.1.5 Dimensions, Resistance, Displacement and Separation —

Recommended Change — Resolve disparity for pushbutton resistance forces. MIL-STD-1132A allows resistances of up to 112 ounces, while MIL-S-227/10/17F recommends a 30-ounce minimum and a 60-ounce maximum. Both documents are discrepant with the resistance in MIL-STD-1472B which requires a minimum of 10 ounces and a maximum of 40 ounces. There are no data in the human engineering literature that would substantiate modifying this provision to concur with the other documents. It is, therefore, recommended that MIL-S-227/10/17F and MIL-STD-1132A be reviewed to determine the origin of their respective requirements, and, if appropriate, these documents should be brought into accord with MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.3 Keyboards —

5.4.3.1.3.2 Layout and Configuration —

a. Numeric Keyboard

Recommended Change — Rewrite the paragraph as follows: The configuration of the keyboard which shall be used to enter solely numeric information shall be a 3x3+1 matrix, with the digits 1, 2 and 3 reading left-to-right in the top row and the zero digit centered on the bottom row (i.e., telephone style).

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical

impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Conrad and Hull (1968, reported in Alden, et al. (1972)) (A-40)

5.4.3.1.3.3 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity for keyboard resistance forces MIL-S-8805/79A calls for a resistance of 6 ± 2 ounces, which exceeds the 5.3 ounce maximum criterion set forth in MIL-STD-1472B. There are no data contained in the human engineering literature to support modifying MIL-STD-1472 to conform to MIL-S-8805. Therefore, it is recommended that the origin of the MIL-S-8805 provision be identified and, if appropriate, that requirement changed to concur with MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.3.5 Multiple Keyboards —

Recommended Change — (new paragraph) Systems containing more than one keyboard shall maintain the same configuration for alphanumeric, numeric and special function keys throughout the system.

Rationale — Problem area reported in HFE T&E during DT II.

Reference — Waters (1979)

5.4.3.1.4 Toggle Switch Controls —

5.4.3.1.4.2 Accidental Activation —

Recommended Change — Add the following statement: "Resistance of lift-to-unlock mechanisms shall not exceed 48 oz."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — MIL-C-81774A.

5.4.3.1.4.2 Accidental Activation —

Recommended Change — Include the following statement: "If a cover guard is used, its location when open shall not interfere with the operation of the protected device or adjacent controls."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

References — MIL-C-81774A, paragraph 3.4.2
Lamps: Human Engineering Design Document (1978)

5.4.3.1.4.3 Dimensions, Resistance, Displacement, and Separation — (Figure 11)

Recommended Change — Adjust table entries as follows: minimum arm length for use by gloved finger = 18mm (.7"); minimum separation for use by gloved finger = 51mm (2.0"); minimum displacement for 2-position toggle switch = 25^{o}.

Rationale — Change is recommended to reduce or eliminate requests for waivers or exceptions to MIL-STD-1472 resulting from unavailability of standard parts meeting the provision.

Reference — Component survey under the present effort

Note: Minimum arm length for use with gloved hand recommended by Woodson and Conover is 19mm (.75").

5.4.3.1.4.3 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity toggle switch displacement, MIL-S-9419D requires a minimum lever travel of 3 to 7 degrees, for a 3-position toggle switch, while MII-S-81619/1A calls for a displacement of 17 degrees. Both documents are discrepant with MIL-STD-1472B which requires a toggle displacement of 18 degrees. There are no data in the human engineering literature to support modifying MIL-STD-1472 to conform to the cited documents. It is recommended that the subject documents be reviewed to determine the rationale for their respective provisions, and, if appropriate, those provisions be modified to conform to MIL-STD-1472.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.5 Legend Switches —

5.4.3.1.5.1 Dimensions, Resistance, Displacement, and Separation —

Recommended Change — Resolve disparity for legend switch resistance. MIL-S-22885/90 requires an activation force between 16 and 80 ounces, while MIL-STD-1472B requries a 10-ounce minimum and a 40-ounce maximum.

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

5.4.3.1.6 Pushbutton-Wheel Switches — Recommended Change: (new paragraph)

5.4.3.1.6.1 Application — Pushbutton-wheel switches should be used for discrete functions when a number of detented positions are required in a fixed sequence (e.g., channel testing).

5.4.3.1.6.2 Shape — The pushbutton surface shall conform to the requirements of paragraph 5.4.3.1.1.2.

5.4.3.1.6.3 Positive Indication — The design of the switch shall provide the operator with a positive indication that the rotary wheel has advanced.

5.4.3.1.6.4 Positions — The number of positions on the rotary wheel should be limited to that required for system operation, i.e., there should be no "dead" positions.

5.4.3.1.6.5 Visibility — The display window shall not obscure any portion of the displayed numeral when viewed from the normal operating position. The display window shall be placed adjacent to the pushbutton such that the operator's hand does not obscure the window during operation.

5.4.3.1.6.6 Design of Rotary Wheel Characters — Rotary wheel characters shall be displayed to conform to paragraph 5.5.5.

5.4.3.1.6.7 Numeral Separation — Numerals on the rotary wheel shall have sufficient separation to ensure that only the displayed numeral is visible.

5.4.3.1.6.8 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement and separation between adjacent edges of pushbutton-wheel switches shall conform to paragraph 5.4.3.1.1.5.

5.4.3.1.6.9 Rotary Wheel Resistance — The rotary wheel advance mechanism's resistance shall be elastic, building up, then decreasing as each position is approached, so that the wheel snaps into position without stopping between adjacent positions.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-52)

5.4.3.1.7 Rocker Switches — Recommended Change (new paragraph)

5.4.3.1.7.1 Application — Rocker switches should be used for functions which require two discrete positions. Rocker switches with three or more positions shall be used only where the use of a rotary control, legend switch control, etc., is not feasible or when the rocker switch is a spring-loaded, center-position-off type.

5.4.3.1.7.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical dangerous or hazardous conditions would result), channel guards or other equivalent means shall be provided.

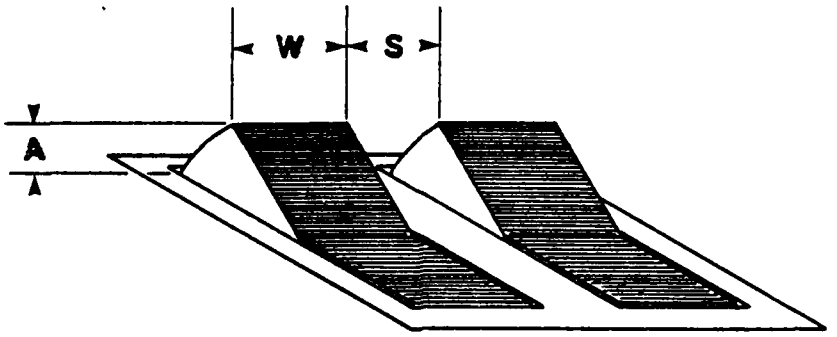
5.4.3.1.7.3 Positive Indication — A positive indication of control activation shall be provided (e.g., snap feel, audible click, associated or integral light, etc.).

5.4.3.1.7.4 Dimensions, Resistance, Displacement, and Separation — Dimension, resistance, displacement and separation between adjacent edges of rocker switches shall conform to the criteria in Figure 12a.

5.4.3.1.7.5 Resistance — Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

5.4.3.1.7.6 Orientation — Rocker switches shall be vertically oriented with activation of the upper "wing" turning the equipment or component on, causing the quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation and actuation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.



	W WIDTH	RESISTANCE
MINIMUM	19mm (0.75")	10 oz
MAXIMUM	38mm (1.5")	40 oz

	S SEPARATION	A DISPLACEMENT	
		2 POSITION	3 POSITION
MINIMUM	13mm (0.5")	30°	18°
MAXIMUM	— — —	120°	60°
OPTIMUM	50mm (2.0")	— — —	25°

FIGURE 12A. ROCKER SWITCHES

Reference — Technical review committee (A-51)

5.4.3.1.8 Multifunction Switches — Recommended Change: (new paragraph)

5.4.3.1.8.1 Application — Multifunction switches should be used when design considerations dictate the use of non-dedicated controls (e.g., single-operator workstations having multiple modes of operation but limited panel space).

5.4.3.1.8.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards, software guarding, or other equivalent means shall be provided.

5.4.3.1.8.3 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement, and separation between adjacent edges of multifunction switches shall conform to the criteria in paragraph 5.4.3.1.1.5.

5.4.3.1.8.4 Positive Indication — A positive indication of control activation shall be provided (e.g., snapfeel, audible click, or integral light). In addition, the displayed function label should be highlighted upon selection. (See paragraph 5.16.1.3)

5.4.3.1.8.5 Location — Functions which occur in more than one mode shall be assigned to the same switch in each mode, unless otherwise dictated by sequential or functional grouping. Related functions shall be grouped together within and between modes.

5.4.3.1.8.6 Labelling — Labels for multifunction switches shall be displayed adjacent to the related control such that the control-label relationship is unambiguous.

5.4.3.1.8.7 Location of Primary Controls — The most important and frequently used controls for each mode shall have the most favorable position with respect to ease of reaching.

5.4.3.1.8.8 Other Requirements —

a. The mode-select switch shall be a dedicated control.

b. The mode selected shall be prominently displayed adjacent to the mode-select switch.

c. A list of available modes of operation shall be provided. The list shall be located and organized in such a manner as to permit the operator to readily determine what action is required to obtain any particular mode.

d. Function label characteristics shall conform to the criteria applicable to the display medium used (e.g., dot matrix).

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-41)

5.4.3.1.9 PC Switch Controls —

5.4.3.1.9.1 Application — PC switches should be used when manual programming functions are required in systems employing printed circuit boards.

5.4.3.1.9.2 Dimensions, Resistance, Displacement, and Separation — Dimensions, resistance, displacement and separation between adjacent PC switch actuators shall conform to the following:

a. Dimensions of actuators shall be sufficient to permit error-free manipulation by the operator using some commonly available stylus (e.g., pencil or pen). The design of the actuators shall not require the use of a special tool for manipulation.

b. Actuator resistance shall be limited to that required to avoid inadvertant activation under expected use conditions. Resistance should gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

c. When actuators are slide-type, they shall have sufficient travel (displacement) to permit easy recognition of switch setting. At a minimum, the travel should be two times the length of the actuator. When actuators are rocker-type, they shall be designed such that the actuated wing is flush with the surface of the module.

d. Actuators shall have sufficient separation to permit error-free manipulation by the operator (i.e., the stylus cannot inadvertantly contact adjacent actuators).

5.4.3.1.9.3 Shape — The surface of the actuator shall be indented to accept the point of the stylus. The indentation shall be of sufficient depth to avoid slippage of the stylus during manipulation.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Technical review committee (A-50)

5.4.3.1.10 Miniature Controls — Recommended Change: (new paragraph)

5.4.3.1.10.1 Application — Miniature controls may be used when severe space limitations exist. Miniature controls shall not be used when available space is adequate for standard-sized controls.

5.4.3.1.10.2 Dimensions, Resistance, Displacement, and Separation — When design constraints dictate the use of miniature controls, the dimensions and separation of the controls shall be the maximum permitted by the available space. Whenever practicable, resistance and displacement of miniature controls shall conform to the criteria specified for the standard size of that type of control.

5.4.3.1.10.3 Other Requirements — All other design considerations (e.g., labelling, orientation, etc.) shall conform to the requirements specified for the standard size of that type of control.

5.4.3.1.11 Slide Switch Controls — Recommended Change: (new paragraph)

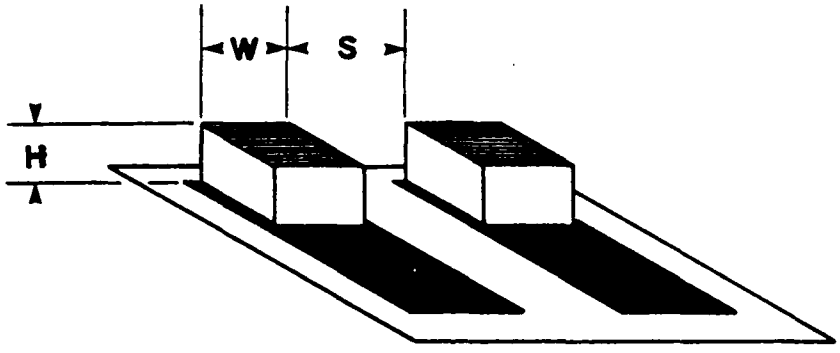
5.4.3.1.11.1 Application — Slide switch controls may be used for functions which require two dicrete positions. Slide switch controls should be used for functions which require a number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (e.g., audio settings across frequencies).

5.4.3.1.11.2 Accidental Activation — When the prevention of accidental activation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards or other equivalent means will be provided.

5.4.3.1.11.3 Dimensions, Resistance, and Separation — Dimensions, resistance and separation of slide switch handles shall conform to criteria in Figure 12B.

5.4.3.1.11.4 Detents — Detents shall be provided for each control setting. Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of stopping between positions.

5.4.3.1.11.5 Orientation — Whenever practicable, slide switches shall be vertically oriented with movement of the slide up or away from the operator turning the equipment or component on, causing the quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation or actuation slide switches shall be employed only for compatibility with the controlled function or equipment location.



	DIMENSIONS			RESISTANCE
	H ACTUATOR HEIGHT		W ACTUATOR WIDTH	
MINIMUM	6.3mm (0.25")	13mm (0.5")	3mm (0.125")	10 oz
MAXIMUM	50mm (2.0")	50mm (2.0")	25mm (1.0")	40 oz

	SEPARATION S		
	SINGLE FINGER OPERATION	SINGLE FINGER SEQUENTIAL OPERATION	SIMULTANEOUS OPERATION BY DIFFERENT FINGERS
MINIMUM	19mm (0.75")	13mm (0.5")	16mm (0.625")
OPTIMUM	50mm (2.0")	25mm (1.0")	19mm (0.75")

FIGURE 12B. SLIDE SWITCHES

5.4.3.1.11.6 Positive Indication — Slide switch controls shall be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle. The pointer shall extend to, but not obscure, the shortest scale graduation marks. When two or more slide switches are grouped together, each switch shall be provided with its own scale graduation marks and setting indications.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Technical review committee (A-54)

5.4.3.2 Continuous Adjustment Linear Controls — Recommended Change: (new paragraph)

5.4.3.2.3 Joystick Controls —

5.4.3.2.3.1 Application — Joystick controls should be used when the task requires precise or continuous control in two or more related dimensions. (The term joystick is used here to refer primarily to controls used for cursor placement. Joysticks used in vehicle control (e.g, cyclic sticks) are described herein as levers). When positioning accuracy is more critical than positioning speed, displacement joysticks should be selected over isometric joysticks.

5.4.3.2.3.2 Limb Support — When precise or continuous adjustments are required, limb support shall be provided to conform to the criteria in paragraph 5.4.3.2.1.4.

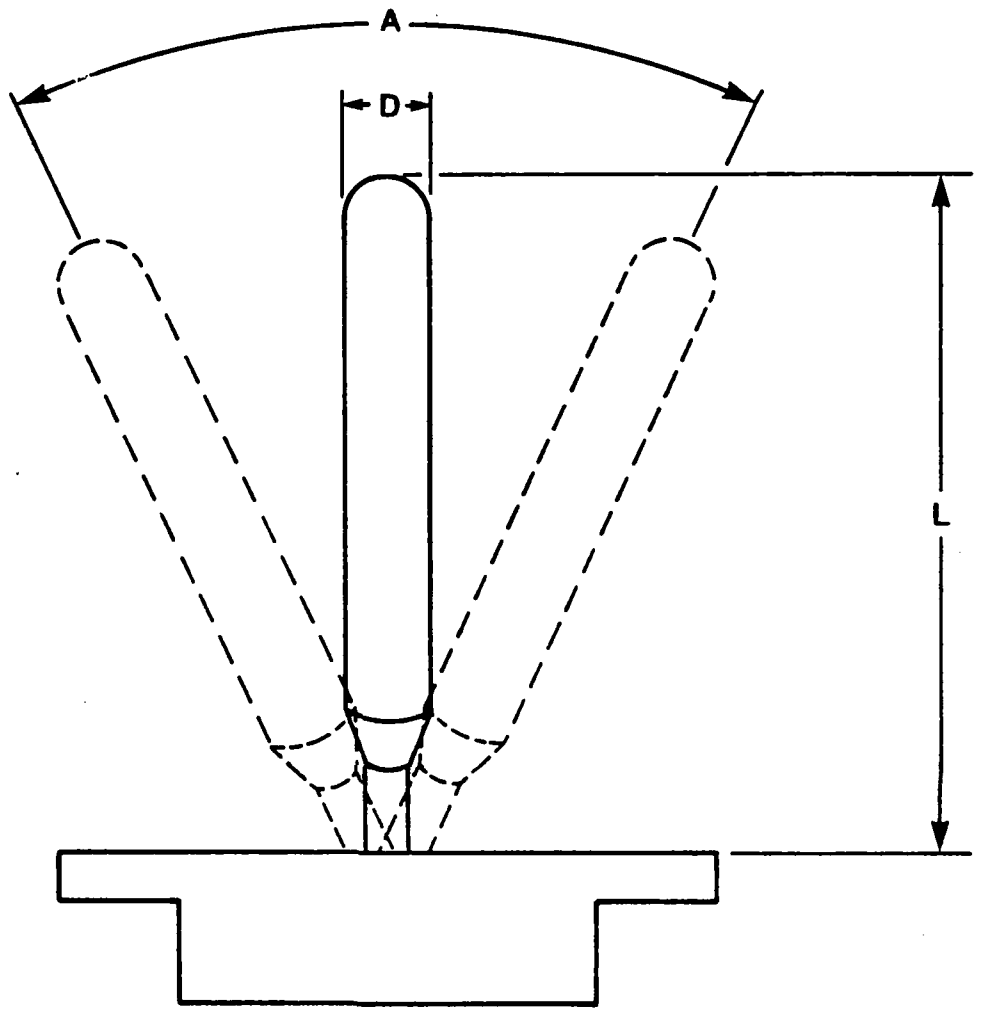
5.4.3.2.3.3 Dimensions, Resistance, and Displacement — Dimensions, resistance and displacement (cone of rotation) for joystick controls shall conform to the criteria in Figure 13a.

5.4.3.2.3.4 Other Requirements —

a. For most applications, joystick controls should be provided with a spring return to center position.

b. The delay between control movement and display response shall not exceed .3 sec.

c. The ratio of the control's displacement to the resulting display movement shall be consistent with the speed and accuracy requirements of the operator.



	DIMENSIONS		RESISTANCE	DISPLACEMENT
	L ARM LENGTH	D DIAMETER		A CONE OF ROTATION
MINIMUM	75 mm (3")	6.5 mm (0.25")	12 oz.	0° *
MAXIMUM	150 mm (6")	25 mm (1.0")	32 oz.	57°
OPTIMUM	— — —	— — —	— — —	5°-20°

* ISOMETRIC (FORCE) JOYSTICK

FIGURE 13-A JOYSTICK CONTROL

d. For precise adjustments in which the operator grasps the joystick "pencil style" below the tip rather than at the tip, the pivot point shall be recessed below the surface on which the wrist rests.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Limb Support, dimensions, displacement, resistance, and spring return: Farrell and Booth (1975) (A-43)

Cone of rotation: Kubokawa and Woodson (1969); Farrell and Booth (1975)

Response delay: AIR Data Store

Control/display movement ratio: Van Cott and Kinkade (1972)

Pivot point: AFSC DH 1-3

5.4.3.2.4 Trackball Controls —

5.4.3.2.4.1 Application — Trackball controls may be used in place of joysticks for functions requiring precise or continuous control in two or more related dimensions. The use of trackball controls should be avoided when associated operator action (e.g., actuate, engage, etc.) is required, since the resulting design would, of necessity, require two-handed operation.

5.4.3.2.4.2 Limb Support — When trackball controls are used to make precise or continuous adjustment, wrist and/or arm support shall be provided.

5.4.3.2.4.3 Diameter — Trackball control diameter shall be not less than 75mm (3") and not greater than 100mm (4").

5.4.3.2.4.4 Resistance — The resistance of the trackball shall be sufficient to preclude inadvertant activation from vibration, movement, etc., in the expected use environment. Resistance shall not exceed 3.0oz, and is preferred to be 1.2 oz.

5.4.3.2.4.5 Surface Velocity — The trackball should be capable of achieving a surface velocity of approximately 28.0 in/sec.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

Reference — Limb support: Technical review committee

Diameter and resistance: Farrell and Booth (1975) (A-46)

Surface velocity: Rogers (1963)

5.5 Labeling —

5.5.4.6 Label Background —

Recommended Change — Revise first sentence to read: "Label background color shall contrast with the equipment background specified in 5.7.9."

Rationale — Change is recommended to maintain clarity and consistency within MIL-STD-1472.

Reference — Lamps: Human Engineering Design Document (1978)

5.5.6.2 Controls and Displays —

5.5.6.2.4 Location —

Recommended Change — Add new provision: "The labeling of concentric controls shall consist of a hierarchy provided by a small solid dot, a larger circle, and a still larger broken circle adjacent to the panel nomenclature for the smallest to largest knob, respectively."

Rationale — Change is recommended to incorporate research findings contained in the human engineering literature that demonstrate a significant and practical impact on human performance. The change is necessary to achieve the objectives specified in paragraph 1.2 of MIL-STD-1472.

Reference — Lamps: Human Engineering Design Document (1978)

Recommended Change — A new section is required to present design criteria for special devices that cannot be encompassed under existing categories (i.e., components used to meet unique operational and/or environment requirements). The following paragraphs are recommended for inclusion in such a section.

5.15 Special Devices — (New Paragraph)

5.15.1 General — Special devices used to meet unique operational and/or environmental requirements shall be designed to optimize human efficienty, safety, and comfort within the constraints imposed by system requirements.

5.15.2 Night Vision Devices —

5.15.2.1 General — Consideration shall be given to designing or selecting night vision devices compatible with the capabilities and limitations of the human visual system.

5.15.2.2 Field Of View — The horizontal field of view (FOV) for night vision devices shall be the maximum obtainable given existing resolution requirements. At a minimum, the FOV shall be 40^{o} for helmet-mounted or goggle-type devices, and 60^{o} for panel-mounted devices.

5.15.2.3 Resolution — For night vision devices employing CRT displays, the minimum resolution shall be 875 TVL for helmet-mounted devices, and 1023 TVL for panel-mounted devices.

5.15.2.4 Frame Rate — Frame rate shall not be less 25Hz.

5.15.2.5 Magnification — For most applications, the use of magnification should be avoided.

5.15.2.6 Signal-to-Noise Ratio — Signal-to-noise ratio for displayed imagery shall not be less than 6.5:1.

5.15.2.7 Other Requirements —

a. Night vision devices employing image intensifier tubes shall have some method of automatic dampening to preclude exposure of the operator to potentially hazardous light levels (i.e., luminance shall not be capable of exceeding 10,000,000 mL).

b. Night vision devices which are designed to be worn by the operator shall be padded to minimize discomfort. The devices shall be designed to accommodate the 5th to 95th percentiles of the expected user population along the following dimensions:

1. Bizygomatic (face) breadth
2. Interpupillary breadth
3. Frontal breadth
4. Nasal breadth
5. Nasal root breadth
6. Nose length
7. Nose protrusion

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — FOV: Johnson, et al. (1977); Sanders, et al. (1975); Holmes (1974); Stich (1974) (A-55)
Resolution: Stich (1974) (A-55)
Frame Rate: Holmes (1974) (A-55)
Magnification: Stich (1974)(A-55)
Singal to Noise Ratio: Humes, et al. (1968) (A-55)
Other Requirements: Technical Review Committee

5.15.3 Head-Up Displays —

5.15.3.1 General — Consideration shall be given to designing or selecting head-up displays compatible with the capabilities and limitations of the human visual system. Information presented on head-up displays shall be limited to critical data which the operator is required to monitor while simultaneously performing some primary visual task.

5.15.3.2 Symbol Brightness — Symbols shall be bright enough to be legible under all expected ambient illuminance. At a minimum, symbol brightness shall be 1,500 ft-L when legibility in direct sunlight (10,000 ft-L) is required. For most high ambient applications, optimal symbol brightness is 2,000-3,000 ft-L.

5.15.3.3 Contrast Ratio — Sufficient contrast shall be provided to ensure symbol legibility under all expected viewing conditions. Specific contrast ratios will vary depending on display medium; however, a minimum contrast ratio of 20% shall prevail.

5.15.3.4 Field Of View — Head-up displays shall have a minimum field of view of approximately 20^{o} in the vertical plane, and 30^{o} in the horizontal plane.

5.15.3.5 Exit Pupil — Head-up displays shall have a minimum exit pupil of 72mm (2.8 in.).

5.15.3.6 Refresh Rate — Head-up displays shall have a minimum refresh rate of 60 Hz.

5.15.3.7 Symbol Line Width — Symbols used in head-up displays shall have a minimum line width of 0.5 milliradians. For most applications, symbol line width of 0.9-1.5mr is considered optimal.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Symbol Brightness: Jenney, et al. (1971) (A-56)
Contrast Ratio: Kelley, et al. (1965); Egan and Goodson (1978) (A-57)
Field of View: Jenney, et al. (1971); Egan and Goodson (1978); MIL-D-81641 (A-59)
Exit Pupil: Van Cott and Kinkade (1972) (A-59)
Refresh Rate: Ketchell and Jenney (1968) (A-60)
Symbol Line Width: Vanderkolk, et al. (1977); Egan and Goodson (1978) (A-60)

Recommended Change — A new section is required to provide guidance in the area of the human-computer interface and dialog. The following paragraphs are recommended for inclusion in this section.

5.16 Human - Computer Interface and Dialog —

5.16.1 Display Format —

5.16.1.1 General — Computer-assisted displays shall be formatted in a manner consistent with the task requirements of the human operator. Data fields, titles, messages, etc., shall be formatted in a logical, consistent manner such that their meanining and inter-relationships are readily discernable to the operator.

5.16.1.2 Data Presentation — Data shall be presented to the operator in a readily usable and readable format. Requirements for transposing, computing, interpolating, or mental translation into other units or numerical bases shall be avoided. When practicable, data shall be presented to conform to the following:

a. Illustrations shall be used whenever possible to supplement or exemplify text.

b. When five or more digits and/or alphanumerics are displayed, and no natural (i.e., population stereotyped) organization exists, characters shall be grouped in blocks of 3 to 4 characters each. Groups shall be separated by a minimum of one blank character.

c. When data fields contain a naturally occurring order (e.g., chronological), such order shall be reflected in the organization of the field.

d. Identical data shall be displayed in a consistent, standardized manner, irrespective of their module of origin.

e. Tasks involving counting shall commence with the number "one," tasks related to measuring shall start with zero.

f. Numbers shall be used as designators when listing selectable items.

g. Lists shall be vertically aligned and left-justified. Indentation should be used for subclassifications.

h. Data which must be scanned and compared shall be presented in tabular or graphic form.

i. The use of hyphenation shall be minimized.

j. When presented in tabular form, alphanumeric data shall be left justified; numeric data shall be right justified by decimal point.

k. Periods shall be placed after item selection numbers, at the end of a sentence, and where necessary for clarification.

l. The use of contractions or shortened forms of words shall be avoided.

m. Each individual field shall be labeled. The operator should not have to rely on contextual cues to identify a field.

n. The following standardized fields shall be used:

- Telephone Number: 914-555-1212
- Time: HH:MM:SS, HH:MM, MM:SS:(.S)
- Date: MM:DD:YY

o. Where lists extend over more than one display page, the last line of one page shall be the first line on the succeeding page.

5.16.1.3 Highlighting — Highlighting shall be used when a particular data item or message is critical to operator decision or action requirements. The following methods of highlighting are acceptable:

a. Contrast enhancement — (i.e., dual level illumination)

b. Blinking — rate between 2-3Hz, with a minimum flash duration of 50 msec

c. Inverse video

d. Graphics — (i.e., the use of highlighting symbology, such as arrows, asterisks, boxes, underlining, etc.)

In all cases, highlighted messages shall provide sufficient figure-ground contrast to ensure prompt operator recognition consistent with the temporal constraints of the task in question.

5.16.1.4 Screen Layout and Structuring — Screen layout and structuring shall be designed to minimize operator scanning and reading requirements, and to minimize the probability of operator error. When practicable, screen layout and structuring shall conform to the following:

a. Displayed data shall be organized in a logical, consistent manner, reflecting some obvious and inherent quality of the data groups (e.g., hierarchical or sequential relationships).

b. Physical location of specific data groups on the screen shall be consistent throughout the operation of the system, irrespective of the module or program in use.

c. Screen layout and separation shall be made apparent to the operator through the use of blank spaces, lines, or some other form of visible demarcation.

d. Lists of options shall be organized according to the probability of selection for each item, with high probability items presented first.

e. Non-option lists or lists of equal-probability options shall be presented in alphabetical or numerical order.

f. Text paragraphs shall be separated by at least one blank line.

g. Formats shall be organized to minimize positioning movements of the cursor.

h. Selection numbers shall be separated from text descriptors by at least one blank space.

i. Items contained in a numbered list and described on "continue" pages shall be numbered relative to the first number on the first page of the list.

j. When directions to the operator accompany a list of options, such directions shall precede presentation of the list.

k. Critical messages requiring immediate operator response shall be highlighted, and, when practicable, placed in the center of the operator's field of view relative to the display or window.

l. The size of the selectable area for an operator option shall encompass, at a minimum, the alphanumeric string of the option designator.

5.16.2 Frame Content —

5.16.2.1 General — Frame content shall be limited to that information required by the operator for a specific action or decision.

5.16.2.2 Feedback — Feedback shall be provided to the operator to indicate the status of system functioning. When practicable, feedback shall conform to the following:

a. When a displayed message or datum is selected as an option or input to the system, the subject item shall be highlighted to indicate acknowledgement by the system.

b. When system functioning requires the operator to standby, periodic feedback shall be provided the operator to indicate normal system operation.

c. When a process or sequence is completed by the system, positive indication shall be presented to the operator concerning the outcome of the process and the requirements for subsequent operator actions.

d. If the system rejects an operator input, feedback shall be provided to indicate the nature of the problem and the required corrective action.

5.16.2.3 Labeling — Each individual data group or message shall contain a descriptive title, phrase, word or similar device to designate the content of the group or message. Where practicable, labeling shall conform to the following:

a. Labels shall be located in a consistent fashion adjacent to the data group or message they describe. The relationship of the label to the group or message being described shall be unambiguous.

b. Labels shall be highlighted or otherwise accentuated to facilitate operator scanning and recognition. The technique used to highlight labels shall be easily distinguished from that used to highlight emergency or critical messages.

c. Labels shall reflect some characteristic common to the group or message being designated. Labels shall be sufficiently unique to preclude operator confusion.

d. When presenting a list of operator options, the label shall reflect the question being posed to the operator.

5.16.2.4 Messages — Messages shall be concise and unambiguous, providing the operator with the information necessary to complete a specific action or decision sequence. When practicable, messages shall conform to the following:

a. Information contained in a message shall be necessary, complete and readily usable. Messages which require the operator to reference external data sources or translate message content shall be avoided.

b. Messages shall contain adequate feedback to the operator to indicate that operator choices or actions have been accepted.

c. Messages containing the digits 0-9 shall be organized in 3x3+1 matrix, with zero centered at the bottom, similar to the telephone keypad.

d. Critical information shall be presented at the beginning of the message.

e. Information required for the next operator entry shall be placed at the end of the message.

f. The terminal's output speed should approximate the mean reading speed of the expected user population. Capability for adjusting output speed should be provided.

g. Messages shall be restricted to factual and informative data. No attempts at humor, sarcasm or other irrelevant modes of presentation shall be made, unless specifically requested by the procuring activity.

5.16.2.5 Interframe Considerations — Interframe design shall minimize the requirements for operator memory. When practicable, interframe design shall conform to the following:

a. When frames are organized in a hierarchical fashion, containing a number of different paths through the series, a visual audit trail of the choices made shall be available upon operator request.

b. When the operator is forced to scroll on a large logical frame, the present and maximum locations shall be presented on the viewable portion of the frame (e.g., line 62 of 112).

c. The operator shall be capable of controlling the amount, format and complexity of information being displayed by the system (e.g., core dumps, program outputs, error messages, etc.)

d. When text is presented in the form of prose, upper and lower case letters shall be used consistent with established orthographic principles, except in cases requiring accentuation (e.g., labels).

e. All data relevant to a specific operator entry shall be displayed on a single frame. Requirements for operator recollection of data between frames shall be avoided.

f. The meaning and context of technical words or phrases shall be consistent between frames.

g. A message occurring in more than one frame shall maintain a constant physical location on the screen. If the message is a variable option list, common elements shall maintain their physical relationship to other recurring elements.

h. Data, text, formats, etc., which have been designated as essential to system performance shall be under system control. Voluntary compliance by the operator shall be avoided.

5.16.3 Command Language —

5.16.3.1 General — Command language shall be written in a logical, consistent manner reflective of the vocabulary and syntax of the expected user population.

5.16.3.2 Abbreviations — Abbreviations shall be used whenever possible to minimize operator input requirements. The use of abbreviations for output shall be avoided. When practicable, abbreviations shall conform to the following:

a. If the operator is using a synonym or abbreviation for a system command name, the system should use the same synonym or abbreviation when referring to that command in messages, prompts, etc., to the operator.

b. Critical operator inputs, responses or actions, in which an error could significantly degrade system performance, shall not be dependent on a single keystroke.

5.16.3.3 Prompting and Structuring — As required, the system shall contain prompting and structuring features designed to request additional or corrected information when an error is detected, and to provide orientation to the operator throughout all interactive sessions. When practicable, prompting and structuring shall conform to the following:

a. When operating in special modes, the system shall display the mode designation and the file(s) being processed.

b. When requesting input from the operator, the system shall prompt the operator in such a manner as to minimize operator input requirements.

c. The system shall be designed to permit correction of individual errors without requiring re-entry of correctly entered data.

d. The system shall contain an historical file of operator entries, in sequence, available upon operator request.

e. Before processing any operator requests which would result in extensive, final and permanent changes to existing data, the system shall display the potential implication of such changes, and require operator acknowledgement.

f. Nomenclature shall be constant for similar or identical functions across components, tasks, and roles for command names, subcommand names, and parameters.

g. Work activities shall be programmed in a closed loop, requiring the operator to issue an explicit command in order to exit.

h. Sign-on processes shall be designed to require minimum input from the operator.

i. Command language shall reflect the operator's point of view, not the programmer's.

j. The system shall be designed to provide hard copy of any frame upon user request. If the copy will be printed remote to the operator, a print confirmation or denial message shall be displayed. Print operation shall not permanently alter screen content.

5.16.4 Recovery Procedures —

5.16.4.1 General — The system shall contain recovery procedures which assist the operator in correcting system-detected errors.

5.16.4.2 Error Messages — The system shall be designed to recognize and report detectable errors. When practicable, error messages shall reflect the following considerations:

a. Feedback — Displayed indication shall be provided which describes the type and location of the error.

b. Directional Guidance — Error messages shall contain instructions to the operator regarding required corrective action.

c. Temporal and Spatial Proximity — Error messages and prompting shall be displayed adjacent to the affected data field as quickly as possible.

d. Corrective Action — Capability shall be provided to the operator to immediately rectify detected errors. This capability shall permit the operator to address the error individually without affecting adjacent entries.

5.16.5 Operator Entry Techniques —

5.16.5.1 General — The design of operator entry techniques shall be compatible with the operational and temporal performance requirements of the operator.

5.16.5.2 Hardware Control Methods —

5.16.5.2.1 Keyboards — Keyboards shall conform to paragraph 5.4.3.1.3, unless otherwise specified by the procuring activity.

5.16.5.2.2 Light Pens —

5.16.5.2.2.1 Application — Light pens may be used when rapid, relatively imprecise input functions are required.

5.16.5.2.2.2 Dimensions — Light pens shall be approximately 12.5mm (0.5 in) in diameter, and 150mm (6.0 in) in length.

5.16.5.2.2.3 Activation — Light pens shall be equipped with a discrete activating mechanism. For most applications, a push-tip switch, requiring 2-5oz. of force to activate, is preferred.

5.16.5.2.2.4 Feedback — Two forms of feedback shall be provided to the operator when using a light pen: (1) feedback concerning light pen placement, preferrably in the form of an illuminated circle projected from the light pen onto the display screen, and (2) feedback that the light pen has actuated and the input received by the system (see 5.16.2.2.a).

5.16.5.3 Cursor Control — Systems employing cursors shall provide cursor control capability consistent with the speed and accuracy requirements of the operator. For most applications, joysticks are the preferred method of cursor control.

5.16.5.4 Entry Mode — The number of required entry modes shall be minimized. Whenever practicable, frames shall be designed to permit the operator to employ a single mode of entry throughout the frame.

5.16.5.5 Selectable Area — The system shall be designed to permit the operator to specify a displayed option by selecting anywhere within the perimeter of the option designator. Selectable areas shall not be contiguous: selectable areas shall be separated by a minimum of two times the width of the selector device.

5.16.5.6 Entry Stacking — When system operation requires the operator to enter a group of logically related entries, the capability for entry stacking shall be provided. A standard character (e.g., slash) shall be designated as an input field separator when using entry stacking.

5.16.5.7 Implicit Prompting — When a fixed length word or collection of characters is to be entered via keyboard, implicit prompting shall be provided in the form of a limited field or special characters (e.g., underscores).

5.16.5.8 Entry Length — Requirements for typed inputs shall be minimized. The length of individual input words (e.g., keywords) should not exceed 5-7 alphabetic characters, and should approximate real words. Whenever possible, numbered option lists and short, meaningful abbreviations shall be used.

5.16.6 Other Requirements —

a. When inserting characters, words or phrases (e.g., editing), items to be inserted shall be collected and displayed in a buffer area of the screen, and then simultaneously inserted by operator command.

b. Data being entered via keyboard shall be displayed, as keyed, on the screen.

c. Mechanical overlays such as coverings over the keyboard or transparent sheets placed on the display should be avoided.

Rationale — Change is recommended to incorporate design criteria for components that are currently employed in military design, or have obvious and imminent military application.

References — Engel and Granda (1975)
Technical Review Committee

4.0 CONCLUSIONS

The results of the present effort demonstrated a significant requirement for modification to MIL-STD-1472, particularly with regard to design criteria for modern controls and displays, as evidenced by the extent of recommended changes to the standard. This, of course, was the expected outcome of the study, given the dramatic growth in control and display technology which has occurred during the six years since the last update of MIL-STD-1472.

In contrast, requirements for modification to the standard to reduce the incidence of requests for waivers were minimal. This was due to a certain extent to the hierarchial structure of the waiver process which generally results in exemption to a specification as opposed to a standard. Of greater consequence, however, is the absence of a central repository or tracking mechanism for waivers. In some cases, waivers were reportedly held by project officers, in others by the contractor, and in still others, they had been forwarded to a higher command. A survey of test officers at various military installations indicated that requests for waiver to MIL-STD-1472 were, at most, infrequent. This conclusion was supported by an examination of 63 Notices of Exemption (NOE) maintained by the F-18 project. Of the NOEs reviewed, 2 (3%) referenced MIL-STD-1472 as the first tier citation. These exceptions were the result of unique design requirements associated with the F-18 and not an inadequacy in MIL-STD-1472. Given the available data, it was concluded that significant modification to MIL-STD-1472 to reduce the incidence of waiver request was unnecessary.

Of particular interest to the authors were the results of an examination of 56 Equipment Performance Reports (EPRs) issued during the DT II HFE evaluation of the PATRIOT missile system. The results of this review indicated the following problem areas to be of sufficient import to warrant issuance of EPRs:

- Work-platform design
  - 4 incidents involving inadequate handholds and guardrails
  - 5 incidents of inadequate footspace or access
  - 6 incidents involving inadequate non-skid surfaces
  - 1 incident involving inadequate throughway
- 4 incidents of hose/cable reversal due to inadequate coding/keying
- 6 incidents in which procedures were inadequate
- 1 incident of inadequate voice communications (open field)
- Workspace

  - 4 incidents involving physical obstruction to access
  - 1 incident of visual obstruction to display
- 1 incident of incorrect control movement to output
- 1 incident of inadequate contrast in hardcopy printout
- 1 incident of inadequate storage provision
- 1 incident of inadequate platform leveling mechanism
- 1 incident of inadvertent activation due to inadequate switch guarding
- 1 incident involving absence of reset for alarm
- 13 incidents of unnecessary exposure to safety hazards.

The above areas were reviewed to determine if proper application of current 1472 provisions could have elminated or attenuated the problems. The results of the review revealed the following:

- Paragraph 5.7.7.6 describes the requirements for exterior personnel platforms and work areas; however, this provision does not provide adequate guidelines for external work platforms (e.g., radar antenna maintenance, cable hookup on S-280 shelters, particularly with regard to requirements for footspace, location, reach, etc.
- Hose and cable keying are covered under paragraph 5.9.14.4.
- Human factors requirements for written procedures are not addressed in 1472.
- Requirements for voice communication in the open field are not specified in 1472.
- Requirements for physical and visual access to components are adequately covered.

It is the authors' studied opinion that further investigation into the nature of EPRs and similar operational data collected during test and evaluation efforts would reveal additional system inadequacies that are directly relatable to a failure to apply MIL-STD-1472. Such an investigation could result in a more stringent application of MIL-STD-1472, with an ensuing improvement in the human engineering qualities of military systems.

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APPENDIX A

COMPONENT DESIGN REQUIREMENTS AND DATA

Displays
Controls
Special Devices

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
Contrast Ratio	1.4:1			Bennett, 1975, cited in Leysieffer, 1975	Comfortable contrast for viewing a CRT in an airborne environment.
	15 (Acceptable)		30 (Preferred)	Rijnsdorp, 1977	
	15 (i.e., C = 88%)		30 (i.e., C = 94%)	Gould, 1968	
			90%	Meister et al., 1969 Heglin, 1973	
	85%			General Electric, 1961, cited in Ketchel & Jenney, 1968	Adequate for most visual tasks.
			50 to 1	Tannas et al., 1978	
Brightness Ratio	2:1 (display:surround)			Meister et al., 1969 Heglin, 1973	
Light/Dark Contrast				Blackwell, 1959, & Shurtleff, 1967, cited in Meister et al., 1969 & Heglin, 1973. Semple et al., 1971	Light symbols on a dark background are recognized more accurately under low ambient lighting. Dark symbols on a light background are recognized more readily under medium and high ambient illumination levels.
Phosphor			D2, V4, V3	Bennett, 1975, cited in Leyseiffer, 1975	Most suitable phosphors for aircraft heads-down displays.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
				Semple et al., 1971	Short persistance phosphors (decay rates less than 10^{-5} sec.) should be used with displays having high regeneration rates of slow image movements. Medium persistance phosphors (decay rates not more than 0.1 sec.) should be used with moderate image movement. Long persistance phosphors (above 0.1 sec. decay time) are best for radar displays where information change is infrequent (30 sec. up to several minutes apart).
			A green phosphor which reduces flicker.	Dickinson, 1979	Since the eye is most sensitive to green, it takes less effort to identify green characters or symbols.
			Best to use phosphors which emit in the middle of the visible spectrum (yellow-green region).	Graham, 1965 & Luckiesh, 1937, cited in Gould, 1968	
	Red symbols on a green background results in the poorest legibility and should be avoided.		Green, yellow, blue or black symbols on a white background.	Burdick et al., 1965	

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
Luminance	80 candela/meter^2 (adequate)		160 candela/meter^2 (preferred)	Rijnsdorp, 1977	
	25mL (Probably adequate assuming adequate contrast)		50mL (preferred)	Gould, 1968	Recommended symbol luminance.
	50 ft-L (acceptable screen luminance)			Meister et al., 1969 Heglin, 1973	
Shades of Gray	7			Miller, 1966; Alluisi, 1957 & Slocum et al., 1967, cited in Ketchell & Jenney, 1968	Slocum et al., did not indicate the empirical grounds for their opinion.
	10			Ketchell & Jenney, 1968	For realistic (commercial) TV images.
			64	Tannas et al., 1978	For good, aesthetic picture quality.
				Johnston, 1968	No reliable differences between 5 & 7 and between 7 & 9 shades of gray. However, on a target recognition task 9 shades of gray result in a significantly greater performance than 5 shades of gray.
Regeneration Rate	50 Hz -- If the illumination is greater than 54 lumens/meter^2 20 Hz -- If the illumination is less than 5.4 lumens/meter^2			Sherr, 1970 cited in Rijnsdorp et al., 1977	

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
			60 frames/sec.	Gould, 1968	For a flicker-free display.
			60 cps	Ketchel & Jenney, 1968	For a flicker-free display.
	30-40 Hz			Meister & Sullivan, 1969	To remove flicker, repetition rate should be at least 50 Hz.
			60 cps	Semple et al., 1971	
			60 cps	Hershberger, 1965	2:1 interlace.
	30-35 Hz			Barmack & Sinaiko, 1966, cited in Meister et al., 1969	Exact rate depends on the display situation, particularly the illumination levels. (For example at *0.01* ft-L, a flicker-free display may be generated at a rate of 20 Hz, but at 100 ft-L, 60 Hz is recommended.
			Above 60 cps	Humes et al., 1968, cited in Levine et al., 1970	The apparent industrial standard of 30 cps may not necessarily be appropriate for military use.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
	Empirically Determined CFF (small fields) (cps) Turnage (1966) Phosphor 10ft-L 32ft-L P-28 34 40 P-19 P-12 25 29 P-7(Y) 32 38 P-1 33 38 P-4(y) 35 41 P-31 37 44 P-20 40 47 * ** Phosphor 50ft-L 100ft-L P-28 31.4 46 P-19 17.5 P-12 32 P-7(Y) 29.8 B,Y 43 P-1 29.2 43 P-4(y) 33.5 B,Y 47 P-31 32.4 51 P-20 32.7 54 * Bryden (1966) **Turnage (1966) Mitchell & Resnick (1960) 10mL 50mL P-1 32 38 P-4(y) 36 43			Gould, 1968	Minimal regeneration rates recommended to prevent flicker for a given phosphor type. Longer persistance phosphors require lower regeneration rates.

DESIGN REQUIREMENTS AND DATA

COMPONENT Cathode Ray Tubes

DESIGN CONSIDERATION	SPECIFICATION			SOURCES	COMMENT
	MINIMUM	MAXIMUM	OPTIMUM		
	50 cps acceptable if display brightness drops to 30 ft-L.		60 cps	Poole, 1966, cited in Ketchell & Jenney 1968	For a flicker-free display at luminances up to 180 ft-L.
	30-35 Hz or greater			Meister et al., 1969	Depending on phosphor.
Signal-To-Noise Ratio	7:1			Rosell et al., 1968, cited in Levine et al., 1970	Minimum S/N ratio required for target detection.
			100:1 Performance as a function of S/N ratio and TV lines over target was still increasing at the heighest S/N ratio (100:1) and TV line frequency (11 lines over target)	Levine et al., 1970	Performance varies as a function of the TV lines over target -- S/N ratio interaction. Therefore, any study on the effects of S/N ratio on performance should also include data on TV lines over target.
	6.5:1			Humes et al., 1968, cited in Levine et al., 1970	Performance improved with increases in lines over target and increases in the S/N ratio (up to 6.5/1. The smaller the target the greater the effect of S/N ratio.
	10:1 (satisfactory) 30:1 (good) 50:1 (excellent)			Bogatov, 1966, cited in Meister et al., 1969	